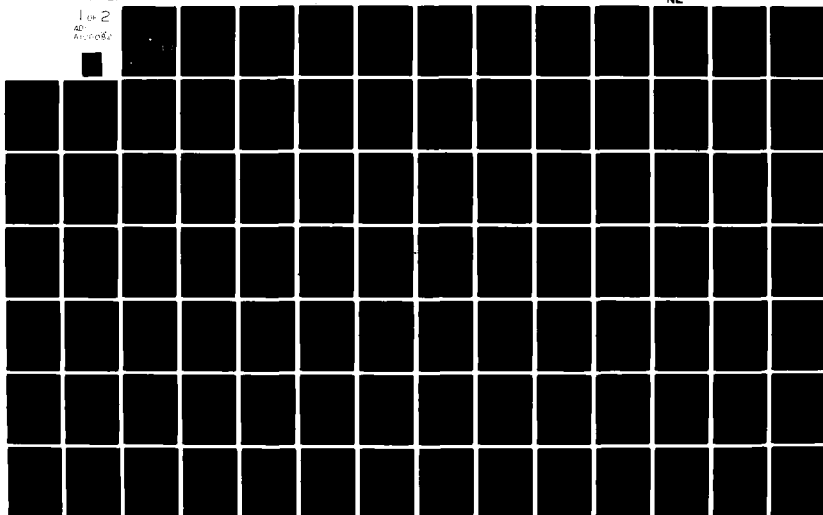


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# Psychological Sciences Division

## 1979 Programs .

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## FOREWORD

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The purpose of this booklet is to present brief technical descriptions of the research contracts which are the responsibility of the Psychological Sciences Division of ONR and to list the technical publications which have stemmed from those contracts during the year. For the convenience of the reader, related contracts have been grouped into clusters as indicated in the table of contents. Each cluster is introduced by text, intended to rationalize and justify the cluster and to provide the reader with help in tying together various contracts within the cluster. These cluster write-ups also contain information regarding the progress made during the year and indicate shifts that have occurred since our last report. Twenty to 30% of our program turns over in the course of a normal year so that 70 or 80% of the work units reported this year are continuations of work that was in progress in the previous year. It is important to remember, therefore, that the technical reports listed under a specific work unit are not usually all of the technical reports produced since that work unit's inception. Technical reports prepared in earlier years under the same contract are not listed. Information regarding those reports may be obtained from previous year's booklets, from the Principal Investigators, or from this office. During this past year, The Office of the Under Secretary of Defense, Research and Engineering reached an agreement with the Congress to report "people-related" research in four functional categories. The reader interested in how our research fits into the Congressional categories is referred to the Index on page 105.

Following the descriptions of the active work units, any work units in a cluster which have been completed during the year are briefly described. All of the technical reports cited are available from the National Technical Information Service (NTIS), Springfield, Virginia, 22161 which processes requests by use of an "AD number" which is shown (if available).

We have also included a section entitled "Archival Publications" containing references to material published in the archival literature within the past year which acknowledges support by the ONR contract research program. It should be pointed out that we are dependent upon an informal, voluntary followup system to obtain these references and this section, although accurate, is undoubtedly incomplete.

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(Dr. Wescourt is on two years detail to ONR  
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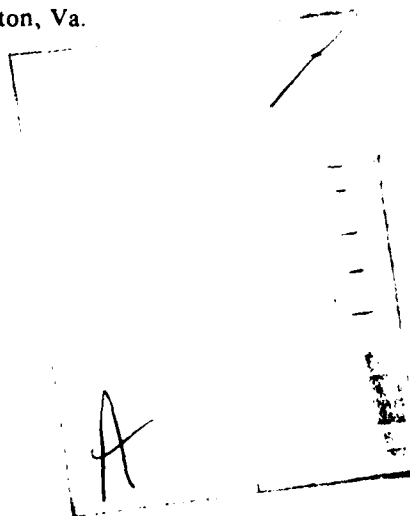
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This booklet is one of several means by which we communicate and coordinate our efforts with  
those of other members of the research community, and it is not intended to stand alone. We  
encourage your comments about any feature of this booklet or about the programs themselves.  
If you wish further information, please do not hesitate to contact members of the staff listed  
above. We welcome your interest in our programs and hope that you will continue to keep us  
informed of related research efforts.

G.L.B.

Arlington, Va.



## PERSONNEL AND TRAINING RESEARCH PROGRAMS

### (CLUSTERS A-E)

The Personnel and Training Research Programs support research which will enable the naval services to more efficiently obtain and utilize qualified personnel. To this end our research efforts are dedicated to methods for assessing people's potential and competence and to methods for rapid, efficient training. Two considerations focus our effort. First, it appears that the best opportunities for increasing the efficiency of assessment and training lie in the individualization and automation of each process. Second, the increasingly technological character of many Navy jobs suggests that cognitive and information-processing skills and aptitudes should receive major emphases. These considerations have led us to support research on objective, quantifiable theories of cognition and information-processing performance of the types required on Navy jobs. Naturally, much of the same research is also concerned with the methodologies needed to exploit theories for the purposes of assessing individual's cognitive aptitudes and competencies, and improving those competencies through training. The work on those theories and methodologies falls into four main clusters.

A. Theory-based Personnel Assessment. Research in theory-based personnel assessment should lead to more efficient and valid psychological assessments for selection, classification, training, and advancement.

B. Information-Processing Abilities. Exploration of individual differences in the basic parameters of information processing is aimed at a clearer understanding of aptitudes and other abilities important in Navy jobs.

C. Instructional Theory and Advanced Training Systems. Work on instructional theories is being undertaken with a view to their application in generative, knowledge-based, automated training systems.

D. Cognitive Processing. A fourth cluster is aimed at models of the cognitive processes and structures underlying skilled performance in real-world tasks with complex information-processing demands.

E. Analyzing Job Demands. In addition to these four thrusts, completed work is described in this fifth cluster. Begun about seven years ago, it is being phased out to make room for investigating other, more promising areas.

### A. THEORY-BASED PERSONNEL ASSESSMENT

A psychological test is a device for obtaining a sample of behavior which can then be transformed into a description of the test taker. Through classification or quantification, such descriptions can frequently be empirically related to other variables of interest. Subsequently, knowledge of these relationships can be used to predict some future behavior of the individuals tested. But this is actuarial science, requiring no special theory about how people behave in the real world. There is no question that it works; over 60 years of testing experience has demonstrated that. But many experts question whether it is the best that we can do.

## PERSONNEL AND TRAINING RESEARCH PROGRAMS

In contrast, theory-based measurement, which forms the cornerstone of theory-based personnel assessment, rests on notions about behavior which go well beyond the strictly empirical data available to the actuary. It begins by assuming that there are certain psychological constructs or traits underlying behavior, and that the performance of individuals can be substantially accounted for by their standing on these traits. These traits themselves are not directly observable; however, their effects on behavior can be measured if we make certain assumptions about the manner in which they affect performance. These assumptions can take many forms, but they generally are mathematical models which relate performance in specific contexts to an individual's standing on the traits.

Unlike the actuarial approach, theory-based measurement allows us to infer performance on unadministered test items from an estimate of an individual's standing on the traits. Thus, one can make comparative statements about individuals even if they have responded to distinct sets of items. This fact makes possible all sorts of innovative approaches to personnel assessment, including computerized adaptive testing.

The work units in this area can be characterized by three distinctive elements: (1) the search for improved measurement models which relate performance on test-like tasks to underlying psychological constructs; (2) the search for improved test administration and scoring procedures; and (3) the search for improved personnel decision-making technology. Basic work supporting the eventual application of computerized adaptive testing in a variety of contexts continues to be the main focus of this work, with substantial gains being made in our understanding of this complex technology. In addition, since virtually all personnel tests in the military are intended for decision-making purposes, we round out this area by exploring a number of ideas for improving personnel decision-making technology.

A variety of vehicles are being employed to coordinate this research with the work of other agencies: (1) ONR sits as a member of the "Computerized Adaptive Testing Inter-service Coordinating Committee," which was established by OSD early in 1979 to study the feasibility of adaptively administering the Armed Services Vocational Aptitude Battery by computer; (2) ONR will continue to sponsor biennial international conferences on computerized adaptive testing with other interested agencies. To date three such conferences have been held with USCSC (now retitled the Office of Personnel Management), AFOSR, DARPA, NPRDC, MEPCOM, and ARI variously joining us as co-sponsors (see NR 150-432 in this cluster); (3) We periodically hold informal meetings of the investigators comprising this cluster. Researchers doing work in related areas for other agencies have also participated. The relative success of these coordination efforts is evidenced by the rapidly growing number of jointly-supported work units, viz., NR 150-427, NR 150-431, NR 150-433, NR 150-395, NR 150-432, NR 150-382, and NR 150-389.

### **STATISTICAL TECHNIQUES FOR GRADED RESPONSE ITEMS IN ADAPTIVE PSYCHOLOGICAL TESTING NR 150-402**

University of Tennessee/Samejima

Latent-trait theories provide coherent methods for predicting and characterizing the responses of examinees to tasks on psychological tests. The use of such theories for building, administering, and scoring Navy tests may greatly increase the efficiency of the testing process as well as the bandwidth and the fidelity of the scores produced. Unfortunately, the psychological basis of the existing latent-trait models needs strengthening, both

in terms of "correctness" and in terms of the generality of their applicability. This research attempts to add that strength by developing an *entirely new and more general latent-trait theory*. Through theoretical, Monte Carlo, and experimental work, the investigator is developing or adapting models of test performance which make more optimum use of the data available. This involves the study of the structure of the responses of examinees to actual test-like tasks, the development of models to characterize these responses, and the development and study of statistical procedures for estimating these models. During its first two years, this planned four-year effort focused on the development of improved methods

for estimating the operating characteristics of item-response categories. The typical estimation methods begin by assuming that the operating characteristic follows some mathematical model, indexed by certain parameters, so that the estimation of the operating characteristic involves the estimation of these parameters. Unfortunately, for theoretical reasons, many testing experts consider this approach to be unsatisfactory, specifically objecting to the forms of the mathematical models used. By attacking the problem from a completely different approach, Samejima has not only avoided the specification of an inadequate mathematical model, but has also managed to reduce the cost of calibration substantially by cutting in half the number of examinees needed for item calibration. The performance of these techniques in a series of Monte Carlo studies was remarkable, reproducing the generating operating characteristic almost exactly. In addition to these studies, the investigator has recently developed an entirely new response model for the binary choice item which may well be a substantial accomplishment in this field. This model represents the first time an investigator has considered explicitly adjusting the metric in order to improve the tractability of the estimation problem and the psychometric quality of the resulting scores. Funding: ONR

Reports:

Samejima, F. Estimation of the operating characteristics of item response categories V: Weighted sum procedure in the conditional PDF approach (Tech. Rep. 78-4). University of Tennessee, December 1978. (AD A063917)

Samejima, F. Estimation of the operating characteristics of item response categories VI: Proportional sum procedure in the conditional PDF approach (Tech. Rep. 78-5). University of Tennessee, December 1978. (AD A063918)

**BAYESIAN PROCEDURES FOR  
ESTIMATION OF PARAMETERS IN  
ITEM-RESPONSE THEORY  
NR 150-427**

University of Massachusetts/Swaminathan

A major element in the use of item-response models (which serve as a basis for adaptive psychological testing) is their calibration. Under present formulations, these models are actually whole classes or families of models, the members of which are indexed by certain parameters. The

problem of calibration is the problem of selecting the member from the family which seems to govern the process for a particular test question by estimating the model parameters. Present approaches use either quasi-maximum likelihood or primitive Bayesian procedures to obtain these estimates. For many reasons these procedures have proved to be unsatisfactory. On the one hand, maximum-likelihood algorithms have been hampered by nonconvergence and very large errors of estimate for reasonably-sized samples. The primitive Bayesian procedures, on the other hand, have introduced unacceptable levels of bias. What Swaminathan is investigating is an entirely new approach to calibration, one based upon "Model-II-Bayesian" procedures. During the six months that this two-year effort has run so far, work has focused primarily on developing a tractable approach to the one-parameter logistic test model. In subsequent phases, lessons learned with this simpler case will be extended to the more interesting two- and three-parameter situations. Funding: ONR, AFHRL

**MODELS AND ESTIMATION PROCEDURES  
FOR THE ANALYSIS OF SUBJECT-ITEM  
DATA ARRAYS NR 154-429**  
Portland State University/Paulson

This one-year effort is, like others in this cluster (viz., NRs 150-402, 150-427, 154-445, and 150-415) concerned with modeling the performance of particular subjects on particular items. But where these others use latent-trait models, Paulson approaches the problem by analyzing subject-by-item performance matrices within an analysis of variance (ANOVA) framework. A central issue for both types of models concerns changes in relative behavior of items from one person to another (e.g., two items may be equally difficult for some people, but differ greatly in difficulty for others). Within Paulson's approach, these changes are reflected in *nonadditivity* of the performance matrix. This work will explore the applicability of an ANOVA model originally developed by Tukey to deal with the general problem of nonadditivity. The research will first attempt to find empirical-Bayes estimators of subject and item parameters using the ANOVA approach. The model will then be explicated to deal with situations such as adaptive testing, where latent-trait theory also applies.

An additional task will be the development of estimators for nonadditivity parameters. This last task is a considerable challenge, since the usual estimators of these parameters are badly biased towards zero and hence underestimate the degree of nonadditivity actually present. Funding: DARPA

**COMPUTERIZED ADAPTIVE ABILITY TESTING NR 150-431**

University of Minnesota/Weiss

Previous simulation studies of the effectiveness of adaptive testing have used item pools which are unrealistic from several perspectives: they assumed that the parameters which describe the items in the pool are error free; they assumed item difficulty and ability distributions which do not necessarily reflect those of real ability tests or examinee populations; and they assumed that the responses of the hypothetical examinees conform precisely to the unidimensional test model under study. Thus, when one attempts to extrapolate from these simulations results to a real testing situation, one typically finds that real examinees and test items do not behave as anticipated. To correct this deficiency in our understanding of the behavior of those techniques, Weiss, in this three-year program now in its first year, will mount a two-pronged attack. First he will employ both Monte Carlo and live-testing techniques in an attempt to evaluate the performance of adaptive testing strategies when errors of various sorts are introduced. Second, he will examine two indices of person-fit to the item-response model in an attempt to develop techniques which, in an operational setting, may help to identify individual examinees whose response patterns seem unlikely if the models hold. In addition, Weiss will be exploring the feasibility of employing alternatives to the multiple-choice format within a computerized adaptive testing environment. Further work will examine the adaptive measurement of information-processing capacities and spatial abilities. Funding: ONR, ARI, AFHRL

**COMPUTERIZED ADAPTIVE MEASUREMENT OF ACHIEVEMENT NR 150-433**

University of Minnesota/Weiss

In training, achievement tests tapping several domains are typically administered at various

points during a sequence of instruction. In such situations, information concerning an examinee's standing within a single domain at a particular time may come from a multitude of sources, including (1) his performance on a test of that domain; (2) his performance on a concurrent test of a related domain; and (3) his performance on relevant domains at an earlier point in the instructional sequence. In previous work (NR 150-389, reported as completed in this cluster), Weiss developed a technique for improving the estimates of an examinee's standing within each of a variety of domains being assessed simultaneously. In this work, in addition to further study of that procedure, he will attempt to formulate procedures for incorporating information from prior assessments. As a prelude to this, Weiss will examine how the dimensionality of achievement changes during a course of instruction. If such changes are not too severe, he will not only examine adaptive testing strategies which make use of this collateral information, but will also study techniques for characterizing individual growth over the instructional interval. Funding: ONR, AFOSR, DARPA, ARI

**DIMENSIONALITY, SCORING AND RELATED PROBLEMS IN INDIVIDUALIZED MEASUREMENT NR 154-445**

University of Illinois/Tatsuoka & Tatsuoka

The scoring of psychological tests using latent-trait models requires an assumption of unidimensionality (i.e., that the responses of all examinees to all questions reflect the action of a single underlying unitary trait). Unfortunately, although we would like to use such models to operationalize adaptive testing, evidence suggests that unidimensionality may be a questionable assumption in an individualized instructional environment. This planned three-year research, just getting underway, will explore the extent and nature of that problem, and will investigate alternative techniques for scoring and branching through criterion-referenced tests, both adaptive and linear. Employing a quasi-experimental design, the investigators will attempt to identify the sources and extent of multidimensionality in criterion-referenced tests intended to measure training progress. Cluster analysis and other procedures will be examined as techniques for partitioning examinees and test questions into subsets within which unidimen-



sionalities obtain. In addition, models which combine response time and accuracy, as well as models based on empirically-derived procedural networks, will be explored as alternative bases for branching through and scoring criterion-references tests. Funding: ONR

**TECHNIQUES FOR  
CRITERION-REFERENCED TAILORED  
TESTING NR 150-395**

University of Missouri — Columbia/Reckase

In the modern test theory and adaptive-testing literatures, a variety of models, calibration and linking procedures, and adaptive strategies have been developed. Although each researcher tends to have his favorites, there exists no coherent body of data which compares the various choices in a reasonably systematic way. In this four-year effort, Reckase is seeking to take a first step in that direction. Specifically, employing both live testing and simulation under conditions likely to exist in a training context, Reckase is exploring: (a) the fit of the procedures to real data; (b) the ways in which each handles multidimensional data; (c) the quality and relationship of trait estimates obtained under each procedure; (d) the data-processing costs and CPU requirements of each procedure; (e) the test information which each procedure yields; and (f) the effects of item-pool characteristics, population characteristics, and characteristics of calibration samples on the operation of the various procedures. In addition, Reckase is exploring techniques for improving criterion-reference measurement and mastery decisions through a combination of adaptive testing and sequential decision-making techniques. Currently in its third year, the research has made substantial progress on each objective. Of special note is the recent work on item-pool-linking procedures which exposed serious deficiencies in all currently available techniques. Funding: ONR, AFHRL

**APPLICATIONS OF STATISTICAL DECISION  
THEORY TO PERSONNEL SELECTION,  
CLASSIFICATION AND GUIDANCE  
NR 150-404**

University of Iowa/Novick

This planned three-year research, just completing its second year, involves the application of statisti-

cal decision theory for improving the total personnel decision-making system. Emphasis is being focused on four major areas: construction of a taxonomy for personnel decision-making; development of a common prediction system for multiple sites; the assessment of utility functions of participants in the decision-making process; and the explication in decision-theoretic models of the components of the taxonomy. The taxonomy for personnel decision-making is based on a four-stage model, Stages G, A, T, and P: Stage G deals with the general manpower pool from which recruiting can occur; Stage A deals with persons recruited into some immediate manpower pool; Stage T is concerned with on-the-job training; and Stage P involves career performance. Stage P represents the ultimate payoff which influences decisions made at all stages. Progress to date includes refining Bayesian statistical techniques which provide a powerful prediction tool when only small samples are available from many locations. In addition, methods for assessment of utilities via interactive computerized dialogue with decision makers have been developed and are being refined in light of emerging understanding of cognitive behavior. Some basic aspects of utility theory have been examined, and a specific consideration of the use of cut-scores has been studied. This latter work also sets forth some classification and assignment rules. Present work centers around the experimental study of utility assessment procedures, further development of decision rules, and completion of the taxonomy of personnel decision-making. Funding: ONR

Reports:

Lewis, C. A note on Bayesian simultaneous linear regression with constant slopes (Tech. Rep. 78-1). University of Iowa, June 1978.

Lewis, C. A note relating two decision systems (Tech. Rep. 78-2). University of Iowa, June 1978. (AD A057698)

Molenaar, I.W. A fast solution of the Lindley equations for the M-group regression problem (Tech. Rep. 78-3). University of Iowa, June 1978.

**THE 1979 COMPUTERIZED ADAPTIVE  
TESTING CONFERENCE NR 150-432**  
University of Minnesota/Weiss

The 1979 Computerized Adaptive testing Conference was an international conference which

focused on the latest research in computerized adaptive testing and latent-trait test theory. The objectives of this conference were (1) to provide psychometricians, statisticians and other currently pursuing work in adaptive testing and related topics with a forum at which to evaluate the state of the art, and to clarify new research questions in these two areas of research; (2) to focus the attention of the broader research community on computerized adaptive testing and thereby stimulate others to do work in the area; and (3) to focus the attention of the DoD testing community on the real potential of this technology, and give them an opportunity to discuss their real-world problems first hand with researchers in the field. (Two earlier conferences on this same theme were sponsored by ONR. The first one, held in Washington DC in 1975, was cosponsored with the U.S. Civil Service Commission. The second, cosponsored with the Air Force Office of Scientific Research, met in Minneapolis in 1977.) This most recent conference was held at the Spring Hill Conference Center in suburban Minneapolis, Minnesota, on June 27 through 30, 1979. Twenty-five papers were delivered, and eight discussants who are leaders in testing research evaluated the presentations. Included also was a symposium of four leaders in the field who discussed the present status and future prospects of adaptive testing and latent-trait test theory. In addition to participation by scientists and managers from DoD and other federal agencies, and leading researchers in the United States, researchers concerned with adaptive testing, latent-trait theory, and military testing problems from Germany, Australia, Austria and Belgium participated. A Conference Proceedings will be issued, and selected papers are scheduled for publication as a book. Funding: ONR, NPRDC, AFOSR, ARI, DARPA, MEPCOM

The following work units in this cluster were completed during the past year.

**COMPUTER-BASED ADAPTIVE  
MEASUREMENT OF INTELLECTUAL  
CAPABILITIES NR 150-382**  
University of Minnesota/Weiss

This work, just completed, was aimed at improving ability-testing techniques for selection and

classification of Navy and Marine Corps recruits. During the three years it has run, the use of computers to adaptively administer ability tests was explored with the objectives of (1) identifying methods of redesigning ability tests for computer administration; (2) determining the psychological effects (e.g., motivation, anxiety, guessing) of computerized administration; (3) utilizing new response formats available in computerized administration; (4) developing methods of adaptive branching for ability-test batteries; and (5) developing new testing approaches uniquely administerable by on-line computers. The research has (1) identified the most promising adaptive-testing strategies; (2) empirically supported theoretical predictions of higher validity for adaptive tests than for conventional tests; (3) indicated that immediate feedback during testing reduces the impact of adverse influences in ability test scores; (4) supported the utility of free-response and other response modes in ability testing; (5) explored the existence of intra-individual multidimensionality in ability-test protocols; (6) indicated the utility of interactive computer administration of tests of problem-solving and memory abilities; and (7) underscored the dangers of careless choice of response models and scoring procedures. The most recent focus involved a cooperative effort with the Navy Personnel R&D Center (NPRDC) to evaluate these ability-testing techniques, using recruits at the Marine Corps Recruit Depot in San Diego. This thrust was specifically designed to examine the generalizability of findings to a military recruit population. A report on this NPRDC study, as well as a final report summarizing the entire effort, is scheduled for late 1979. Funding: ONR, NPRDC, AFOSR

Reports:

Prestwood, J.S., Weiss, D.J. The effects of knowledge of results and test difficulty on ability test performance and psychological reactions to testing (Tech. Rep. 78-2). University of Minnesota, September 1978. (AD A060876)

Pine, S.M., Church, A.T., Gialluca, K.A., & Weiss, D.J., Effects of computerized adaptive testing on black and white students (Tech. Rep. 79-2). University of Minnesota, March 1979. (AD A067928)

**COMPUTERIZED ADAPTIVE  
PERFORMANCE EVALUATION NR 150-389**  
University of Minnesota/Weiss

## PERSONNEL AND TRAINING RESEARCH PROGRAMS

This three-year effort was the first to investigate the application of adaptive testing techniques to the special problems raised by the measurement of achievement. Research concentrated on the application of latent-trait test theory to problems of adaptively measuring achievement. Results indicated that (1) the application of modern test theory and adaptive testing techniques to the achievement-testing problem can result in tests less than half the length of conventional tests, and with higher levels of measurement precision (at least for some individuals); (2) adaptive achievement tests, with half the number of items, can have validities equal to those of conventional tests; (3) multicontent achievement tests can be reduced in length drastically without decreasing measurement efficiency, with *intersubset* branching accounting for less of the reduction than *intrasubset* branching; (4) the use of immediate feedback of results to examinees during the process of achievement testing does not adversely affect the measurement properties of the test; (5) achievement can be measured on the same dimension for several weeks after instruction is completed, but that pretests may measure a different achievement variable; (6) the mastery (criterion-referenced) testing problem can be conceptualized in modern test theory terms; and (7) the problem of measuring individual achievement as a function of "growth" over time in instruction can be resolved by a joint application of specially designed adaptive testing techniques based on latent-trait theory. The work has also contributed basic knowledge to the use of latent-trait test theory in an achievement testing environment, and made available a set of general-purpose computer programs for use in scoring test data with latent-trait test models. A final report is in preparation. Funding: ONR, DARPA, NPRDC, ARI, AFOSR

### Reports

Bejar, H., Weiss, D.J. A construct validation of adaptive achievement testing (Tech. Rep. 78-4) University of Minnesota, November 1978. (AD A063148)

Bejar, H., Weiss, D.J. Computer programs for scoring test data with item characteristic curve models (Tech. Rep. 79-1) University of Minnesota, February 1979. (AD A067752)

Kingsbury, G.G., Weiss, D.J. Relationships among achievement level estimates from three item characteristic curve scoring methods (Tech. Rep. 79-3) University of Minnesota, April 1979. (AD A069815)

See ARCHIVAL PUBLICATIONS: Bejar & Weiss, in press (a), (b); Kingsbury & Weiss, in press; Weiss, 1979.

## PSYCHOMETRIC THEORIES OF REACTION TIME AND PERFORMANCE NR 150-415 University of Illinois/Tatsuoka

One of the major problems encountered in trying to assess the psychometric characteristics of criterion-referenced achievement tests is that they typically yield scores which are uniformly quite high, but with little variability. As a result of this lack of variability, when one tries to assess reliability and validity in the usual way by calculating product-moment correlation coefficients, these measures often turn out to be embarrassingly low. In examining test data from a computer-based training program, Tatsuoka noticed that, while the scores themselves varied little, the time taken to respond to the items was quite variable. She reasoned that if response time was reliably related to the trait being measured, it might be combined with accuracy-of-response data in scoring the test. This 18-month research effort represented an attempt to follow through on that idea. Although the Principal Investigator was unsuccessful in her attempt to integrate these two sources of information into a single coherent model of test performance, she was able to make substantial strides in modeling each source separately. She constructed a model which makes sense of individual differences in response time. A subsequent validation study revealed that identified differences in response time were related to identifiable differences in instructional treatment. A model of response appropriateness was also developed which promises to overcome serious shortcomings in extant procedures. A final report, now in preparation, will review key findings and discuss theoretical and practical implications. Funding: ONR

## B. INFORMATION-PROCESSING ABILITIES

We anticipate that the psychometric techniques being explored in our adaptive-testing research will complement the psychological processes and techniques which are the subject of our research on information-

processing abilities. Whereas conventional psychological measurement relies purely on the actuarial criterion of their success in distinguishing high- and low-ability individuals, our research seeks to directly measure the basic information-processing operations that underlie the target abilities. Hence, we are studying the implications of individual differences in the parameters of certain basic information-processing operations. We are also looking at the performance of complex tasks as a function of proficiency in the basic information-processing components underlying those tasks. Finally, we are concerned with the potential of information-processing theories to provide substantive explanations of the relationship between mental-test performance and performance in real-world tasks.

The abilities under study in this research are of importance in two general ways. First, abilities such as reasoning and remembering are components of aptitude in that they are required in the course of effective learning. For this reason our research on these abilities has application to Navy efforts on individualized instruction and training of a more heterogeneous recruit pool. Second, abilities such as those relating to attentional allocation and capacity are heavily involved in the operation of aircraft and other complex, high-demand systems. For this reason our research provides the technical base for a rapidly emerging technology (being developed by more applied activities, such as NAMRL) in personnel selection for such jobs.

Work is coordinated and passed to applied interests through both formal and informal conferences. The second contractors' conference in this area was held in New Orleans in February of 1979. At that meeting, ONR contractors exchanged presentations with various military agencies, namely, NPRDC, NAMRL (Pensacola), NAMRLD (New Orleans), ARI, and the Army's Training Systems and Analysis Command (White Sands Missile Range). Contacts between individual contractors in this cluster have been established with various Navy labs: NAMRL, NAMRLD (New Orleans), NSMRL, NPRDC, and NHRC. Also, through the joint sponsorship of Code 458 and ONR-London's Window-on-Science program, Dr. Alan Baddeley, Director of the Medical Research Council's Applied Psychology Unit (Cambridge, England), was brought to the U.S. to visit ONR Headquarters, selected Navy laboratories and several ONR contractors, and to attend the contractors' conference described above.

**COMPONENTIAL ANALYSIS OF HUMAN  
INTELLIGENCE AND INFORMATION  
PROCESSING NR 150-412**  
Yale University/Sternberg

This work (initiated in FY 78 and expected to run for five years) formulates and evaluates a general theory of the components of human intelligence. These components are theorized to be of five kinds: *metacomponents*, used to plan, control, and monitor execution of tasks requiring intelligence; *performance components*, used in the actual execution of these tasks; *acquisition components*, used in learning how to solve tasks; *retention components*, used in remembering how to solve tasks; and *transfer components*, used in carrying over knowledge about how to solve a task from one task to another. Early research sponsored by the contract was devoted to understanding individual differences in task performance by identifying basic individual differences in the performance components used in task solution, the representa-

tions upon which these components act, the strategies into which these components combine, the consistency with which these strategies are executed, and the speed and accuracy of component execution. These various aspects of performance were related to each other, and to performance on standardized reference sets of mental abilities. More recent research extended these and other kinds of analyses to understanding figurative speech such as metaphor and simile. Current research is divided into three major subprograms. One deals with the isolation of metacomponents from analogical and other reasoning tasks, based on the belief that individual differences in metacomponential abilities are largely responsible for differences in measured intelligence. A second area of research deals with the isolation of acquisition, retention, and transfer components from tasks requiring people to learn meanings of words presented in ordinary, everyday contexts. The last area concerns training of strategies and metastrategies of reasoning. Here the particular concern is

with matching the form of training given to the ability pattern of the individual, and with discovering what it is about certain strategies that makes them more efficient than others. Funding: ONR

Reports:

Sternberg, R.J. A proposed resolution of curious conflicts in the literature on linear syllogisms (Tech. Rep. 8). Yale University, June 1978 (AD A058316)

Sternberg, R.J. The nature of mental abilities (Tech. Rep. 9). Yale University, June 1978 (AD A057965)

Sternberg, R.J. Psychometrics, mathematical psychology, and cognition: confessions of a closet psychometrician (Tech. Rep. 10). Yale University, June 1978 (AD A057966)

Tourangeau, R., Sternberg, R.J. Understanding and appreciating metaphors (Tech. Rep. 11). Yale University, June 1978 (AD A058318)

Sternberg, R.J. Representation and process in transitive inference (Tech. Rep. 12). Yale University, October 1978 (AD A062586)

Sternberg, R.J., Tourangeau, R. Aptness in metaphor (Tech. Rep. 13). Yale University, October 1978 (AD A062489)

Sternberg, R.J. Contrasting conceptions of intelligence and their educational implications (Tech. Rep. 14). Yale University, November 1978 (AD A062583)

Sternberg, R.J., Weil, F.M. An aptitude-strategy interaction in linear syllogistic reasoning (Tech. Rep. 15). Yale University, April 1979

Sternberg, R.J. Intelligence tests in the year 2000: what forms will they take and what purposes will they serve? (Tech. Rep. 16). Yale University, April 1979 (AD A068499)

Sternberg, R.J. New views on IQs: a silent revolution of the 70s (Tech. Rep. 17). Yale University, April 1979

See also ARCHIVAL PUBLICATIONS: Sternberg, 1978 (a), (b); Sternberg, 1979; Sternberg, in press (a), (b), (c), (d); Sternberg & Detterman, 1979; Sternberg, Guvote, & Turner, in press; Sternberg, Tourangeau & Nigro, in press; Tourangeau & Sternberg, in press

# **PROCESS ANALYSES OF APTITUDE FOR LEARNING NR 154-426**

Stanford University/Snow

This research derives from evidence gathered in an earlier effort (see NR 154-376) that (1) abilities measured by aptitude tests can be represented in terms of information-processing activities involved

in test performance; (2) aptitude tests can be used to predict not only learning outcome under instructional and training conditions, but also individual differences in learning activities engaged in by learners during computerized adaptive instruction; and (3) individual differences in information-processing activities in ability-test performance and in learning activities in instruction may be explainable in common terms. An hypothesized interpretation based on the notions of "assembly" and "control" as executive processes in aptitude and learning performance was constructed. The current research, in its first year of a planned three-year program, is designed to experiment on assembly and control processes directly, in both laboratory-task performance and in real instructional studies. These experiments will test the adequacy of flow chart models of test performance representing the well-known ability factors and relations between them. They will aim to elaborate such models for families of tests already shown to be related correlationally. They will further test the degree to which individual differences in "general" central aptitudes such as  $G_c$  and  $G_f$  can be interpreted as assembly and control variations in test-performance programs. Initially, "assembly" processes are conceived as cognitive operations that serve to organize or reorganize a set of performance steps into a coherent information-processing strategy for a given task. "Control" processes are thought of as operations serving to evaluate and adapt the information-processing strategy as it is applied in performing a task. "Assembly" would include learning and retrieval functions relevant to the task, while "control" would include motivational functions associated with attention and persistence through the task. The objective of the proposed research is to explicate these crude initial definitions. It is not clear that sources of test-score variance associated with assembly and control functions can be separated empirically from one another, or from that of primary performance processes. The laboratory experiments would seek to test this possibility. The planned research will also attempt to map the kinds of processing differences identified above into analogous representations of individual differences in learning activities. An additional aim is to begin to identify personal-motivational aspects of aptitude for learning, and to build hypotheses relating such aspects to the cognitive-

processing model derived from the earlier research. The general aim is to build a process theory of aptitude that will be useful in understanding individual differences in learning, and in adapting instruction to such differences. Funding: ONR, DARPA

**STRUCTURAL EQUATION MODELS OF  
VERBAL MEMORY NR 150-443**  
UCLA/Woodward

This new work will, within the next two years, formulate and evaluate a new mathematical approach to "process models" and individual differences. The work will be focused on the area of verbal learning and verbal ability. The information processing aspects of such learning may be viewed in terms of: primary (short-term) and secondary (long-term) memory, the operations transferring information from one of these memories to another, and the processes which input and retrieve information from the system. A set of structural equations will be formulated to represent these components and relate them to independent variables (e.g. presentation rate), individual abilities, performance, and ancillary process indicators such as pupil dilation. In addition to a test of the basic principles of the resulting model, the investigators will also work with more elaborate versions addressing special issues. Such issues include two-process models of recognition and recall, the different roles of spatial and verbal ability, proactive interference, and distribution of practice. Funding: NSF, ONR

**COMPONENTS OF MENTAL IMAGERY  
NR 150-442**  
Harvard University/Kosslyn

This new effort examines individual differences in mental imagery in terms of a theory which Kosslyn has been formulating over the past few years. The theory holds that mental images are spatial arrays generated from deeper conceptual knowledge. Activation in the array decreases from the center out. The entire array fades with time (and must be refreshed). There are also limits on the spatial resolution of the array. Conceptual knowledge used to generate the image consists of perceptual memory for objects and propositional knowledge

about their properties. There are certain processes which can generate images from conceptual knowledge and other processes that transform (shift, rotate, etc.) mental images. A third set of processes is used to inspect the image. This work will, in its first year, create a battery of instruments for selectively assessing the parameters of an individuals' mental-imagery components and processes. Such parameters include, for example, the resolution of the image or speed of various transformations. The second and final year will be used to determine the relationship of these parameters to tasks which are thought to rely heavily on mental imagery. Two candidates for such tasks are relative-motion determination and comprehension of exploded-view diagrams. Funding: ONR

**MEASUREMENT AND ANALYSIS OF  
PERCEPTUAL AND COGNITIVE ABILITIES  
IN VERBAL INFORMATION PROCESSING  
NR 154-386**

Bolt Beranek and Newman/Frederiksen

One of the most complex and important combinations of basic information-processing components is that found in reading and verbal information processing. This research is concerned with understanding and identifying the limits on reading ability imposed by deficiency in these components. During the first two years of a planned three, the work has identified perceptual and cognitive skill components of reading, and has formulated techniques for measuring those skills. A series of experiments has pinpointed poor readers' deficiencies in encoding orthographic units, in using context in lexical identification, and in exploiting sequential redundancy within a single eye fixation. Some 14 measures of these and other processes have been related to five basic components of reading: letter encoding, multi-letter encoding, phonemic translation, articulation, and lexical access. Confirmatory maximum-likelihood factor analysis has been used to assess the model and establish its relationship to conventional reading tests. Research in the past year has been conducted to establish the effects imposed by semantic constraints on lower-order processes such as multi-letter encoding and orthographic translation. The emphasis in current research is on investigating the rules used by readers in understanding the

various cohesive forms of English. Studies of the effects of staging of ideas, topicalization, syntactic form, number of available referents, and other text variables on subjects' performance in comprehending anaphoric reference are leading to a set of rules used by readers in assigning text referents, and to the beginnings of a theory of a discourse processing. Funding: ONR

Report:

See ARCHIVAL PUBLICATIONS: Frederiksen, in press (a), (b).

### **A COMPONENTIAL APPROACH TO READING AND CORRECTING READING DISABILITIES NR 154-440**

Harvard University/Weaver

This new work, planned to continue for three years, is based on the work described above (NR 154-386) which produced a componential theory of reading and reading proficiency. This work will determine, through measurement and training studies, how the theory can be used to isolate the reading problems of young adults with literacy problems. Three major types of processes may be identified within the theory. Word analysis processes operate from the bottom up to allow the identification of words as isolated sensory inputs. Discourse analysis processes are responsible for construction of semantic and syntactic representations of the text, and integrative processes are responsible for integrating information across the two levels. The component processes of each of these major classes operate simultaneously and interdependently. Thus, deficiencies at one level will spread and have effects at other levels. Similarly, special strengths in one component may serve to compensate for weaknesses in other processes. Training procedures which operate selectively on particular components and which collectively span the range of components will be fashioned into microcomputer-hosted games and incorporated into several four-to-six week training studies. Data from these studies will be used to examine how training at one level generalizes to other levels. This knowledge will, in turn, be used to generate procedures for optimizing remedial programs for reading-deficient adults. Funding: ONR

### **DETERMINANTS OF COGNITION DURING THE PRIME ADULT YEARS NR 150-438**

University of Washington/Hunt

A great deal is known about the cognitive capacity of post-adolescents and young adults. And there is emerging a substantial literature on the cognitive capacity of the aged (i.e., those past retirement age). Very little is known, however, about cognitive change from ages twenty to fifty, even though this is the age range that covers the majority of our working lives. Much of the relevant literature does not deal with age directly, but rather deals with cognitive responses to incidents statistically associated with ageing, such as hypertension, stroke, life stress, and alcoholism. This new effort scheduled to run for two years, is intended to produce a literature review that will present a unified picture of cognitive change over what is usually the most productive thirty-year span of an individual's life. Besides reviewing the literature, consultations have been arranged with persons both in and out of the Navy who are in a position to estimate the practical effects of the age-related cognitive changes indicated by the scientific literature. In addition to preparing a picture of our present knowledge concerning cognitive changes over the working years, the report will suggest priorities for research studies in the area. Funding: ONR

### **INDIVIDUAL DIFFERENCES IN AUTOMATIC AND CONTROLLED HUMAN INFORMATION PROCESSING NR 150-409**

University of Illinois/Schneider

Prediction of performance in complex tasks requires a knowledge not only of an individual's proficiency in the components of the task, but also of the general information-processing load imposed by each component. Schneider's earlier work formulated a theory which classified detection tasks in this regard. Such tasks involve *control* processing when accomplished via a slow, serial, capacity-limited process which imposes a considerable cognitive load. By contrast, *automatic* processing takes place over a fast, parallel, capacity-unlimited channel which imposes little, if any, cognitive load. The latter processing can take place only after extensive training under conditions of consistent stimulus-response mapping. This effort, now in its

second of a planned three-years, is concerned with the implications of this theory for individual differences and performance prediction. One series of studies is attempting to relate such differences to speed, accuracy, and attentional load in detection and choice-reaction time tasks involving control processing. A second series is addressing individual differences in the learning of automatic processing. This will be accomplished by the fitting of learning models to individuals and examining the parameters relating to learning rate, asymptotic performance and reversal-learning rate (following a change in stimulus-response mapping). A third series of experiments is examining the simultaneous operation of automatic and control processes in independent tasks presented jointly. Finally, a fourth series of experiments seeks to explore the limits of automatic processing by increasing the number of channels, complexity of target stimuli, and complexity of the stimulus-response mapping. Results to date have shown: 1) subjects can perform simultaneous operations of automatic and control processing with no decrease in sensitivity relative to the single task; 2) there are little or no vigilance decrements in automatic tasks (vigilance decrements are a serious factor in control processing); (3) individual differences in control processing were not predictive of automatic target search performance, but college entrance examination scores were. Funding: ONR

#### **PARAMETERS OF VISUAL SEARCH CAPABILITY NR 150-425**

University of Delaware/Hoffman

This research, which is related to that described above (NR 150-409), is concerned with a theory of cognitive-capacity allocation in visual search. One widely held view characterizes the process of "automatic" search and detection by humans as occurring via a fast, relatively unlimited-capacity process which requires little apparent mental effort. Specific objectives of this work are to formulate a stage model of visual search, determine how speed and automaticity of search develop, and identify the best predictors of an individual's capacity to achieve such automaticity. To test the model, experiments are being conducted under a variety of search conditions, including those which are believed to foster, as well as discourage, the

development of automaticity. Results during the first year, just completed, are surprising in that they indicate that "automatic" processing may draw attentional resources away from a concurrent (secondary) task. These results have led us to extend the work for another year in order to examine further the nature of such dual-task interactions. Work will also continue on estimating the parameters of search processes for individuals, and relating these estimates to performance on selected ability tests and other information-processing tasks. Funding: ONR

#### **PREDICTION OF PERFORMANCE IN DIFFICULT TASKS NR 154-398**

University of Washington/Hunt

The aim of this work, now in its final year, is to develop a general theory for the prediction of performance on complex tasks from measurement of proficiency in their simpler constituents. The research complements that by Keele and Hawkins (see NR 150-407 below in this cluster). Such a theory could assist in developing techniques for predicting performance in difficult situations without having to expose personnel to those situations directly. The research focuses on the proposition that complex tasks draw upon a reservoir of spare capacity that varies from individual to individual. The demands of a single task on this pool can be measured by degradation of performance on a concurrent secondary task. This technique has been successfully validated in three separate situations: the degradation in simple reaction time due to variations in memory load on a concurrent task; degradation in memory capacity due to stresses imposed by concurrent verbal reasoning; and degradation in a psychomotor task due to stresses imposed by problem solving on a non-verbal intelligence test (the Raven Matrix test). No evidence has been found for the existence of a specific ability to "time share" tasks. If two tasks are done separately, measures of performance on the individual tasks will predict performance when the two tasks are done simultaneously. Although the general assumption that a secondary task taps the attentional resources "left over" from the primary task does lead to a reasonable summary of most of the data, some aspects of the results are not compatible with this view. It is very difficult for a person to avoid letting the presence of a secondary



## PERSONNEL AND TRAINING RESEARCH PROGRAMS

task interfere with primary-task performance. Models of how a person allocates attention to primary and secondary tasks are now being developed. Funding: ONR

### Reports:

Hunt, E. A proposal for the evaluation of biological influences upon cognition (Tech. Rep. 3). University of Washington, March 1979.

Hunt, E., Lansman, M. & Wright, J. Some remarks on doing two things at once (Tech. Rep. 4). University of Washington, April 1979. (AD A069574)

Hunt, E. Intelligence as an information processing concept (Tech. Rep. 5). University of Washington, May 1979. (AD A069953).

### MENTAL RESOURCE ALLOCATION AND SPECIALIZATION OF THE CEREBRAL HEMISPHERES NR 150-441

University of Colorado/Friedman & Polson

This research, a planned two-year effort just begun, represents an attempt to combine current knowledge in the field of human-resource allocation with knowledge about cerebral specialization of information processing, in order to predict dual-task performance in cognitive and motor tasks. The first phase of this effort involves completing the development of an independent-resources theory of cerebral specialization. In this theory, it is assumed, for a given individual or subpopulation of individuals performing in a particular stimulus and task domain, that (a) each hemisphere has its own performance-resource function which may or may not be the same as that of the other hemisphere; and (b) each hemisphere has its own pool of resources which is inaccessible to the other hemisphere. The second phase will involve carrying out a series of experiments which are designed to test certain predictions of the theory concerning performance interactions in dual-task situations when the target and load task are performed primarily by one or the other hemisphere. This will involve using load tasks of varying levels of difficulty, as well as target tasks which require varying levels of processing, where both the load and target tasks have been deliberately designed to require the resources of either the right or the left hemisphere.

Resource allocation between the target and load tasks will be varied by using monetary payoffs, so that performance-resource functions can be obtained for each hemisphere. Funding: ONR, AFOSR

### PERFORMANCE AND THE PSYCHOPHYSICS OF MENTAL WORKLOAD UNDER CONCURRENT TASK CONDITIONS NR 150-439

University of Oregon/Hawkins

This one-year effort is concerned with the ability of individuals to rate the relative mental demands of particular information-processing tasks. The Navy is relying on such judgements to aid in the design and test of high-demand complex configurations such as aircraft cockpits. This work grew out of a basic research need by the Pacific Missile Test Center (Pt. Mugu, CA) to validate the rating approach, and will capitalize on other, related work by Keele and Hawkins described below (NR 150-407). Hawkins will, as part of this effort, conduct a literature review on the psychophysics of mental workload. The empirical aspect of the work will focus on a paradigm in which subjects perform memory scanning and visual discrimination in rapid alternation. Workload will be varied by manipulating the parameters of each task (e.g., target set size in memory scanning). Objective measures of workload will be derived from empirical functions relating error rate to task-alternation frequency. These objective measures will then be used to assess individual subjects' ability to judge workload. In addition to its relationship to other work in this cluster (e.g., NR 150-441, above), this research is also related to Cluster O, Man-Machine Interface (see NR 196-158). Funding: PMTC

### COGNITIVE-FACTORS ANALYSIS OF SKILLED HUMAN PERFORMANCE NR 150-407

University of Oregon/Keele & Hawkins

This research takes a cognitive factors approach to the problem of predicting complex task performance from simple tasks. Work during the second year of this three-year program focused on three hypothesized cognitive ability factors: cognitive flexibility, time-sharing, and in distractibility. One series of experiments has been directed

toward the refinement of measures of *cognitive flexibility* (the ability to rapidly redirect attention in accord with emergent priorities). Another series has isolated several specific and uncorrelated *time-sharing* subabilities which, *in combination*, may play an important role in determining performance in complex, multiple-task situations. Work has just begun on experiments designed to determine whether or not inattention is a general cognitive ability. Along a different vein, a computer-controlled aircraft simulation has been developed and applied to a group of private pilot instructors. Performance on the simulation has been found to correlate with aviation experience. The simulation will be used as a criterion measure in experiments assessing the predictive validity of the cognitive factors isolated in the research program. Funding: ONR

See ARCHIVAL PUBLICATIONS: Hawkins, Rodriguez & Reicher, 1979.

#### **TRAINABILITY OF BASIC ABILITIES**

**NR 154-400**

Advanced Research Resources  
Organization/Fleishman

This effort is based on Fleishman's previous research on human abilities. That work, using an extensive refinement of factor-analytic approaches to job performance, suggested that such performance could be accounted for in terms of some 37 abilities. This work is exploring the proposition that these abilities may be trainable, and that certain training procedures for a particular ability will produce a high degree of transfer to all tasks which demand that ability. During its first year, this exploration included a literature review on nonspecific transfer. The review found no specific research on ability training, but studies of learning to learn and of simulator training indicated that ability training was a promising research avenue. Empirical work the second year concentrated on the selection of abilities for training, and the design of transfer studies. An experimental design which allows evaluation of the breadth and extent of ability training was developed and implemented to assess flexibility of closure. Sixty undergraduate college students participated in a study of from one to five days duration. Experimental subjects received extensive practice with feedback provided

on a set of tasks known to require the abilities of flexibility of closure and spatial scanning. Control subjects received no practice. All subjects were tested on an electronic fault-finding task which was dissimilar to the training tasks, but which had earlier been demonstrated to require for successful task performance the abilities being trained. Results indicated that training significantly enhanced spatial scanning but not flexibility of closure as measured by standard ability tests administered before and after training. On the other hand, there was no evidence that performance on the troubleshooting task was affected significantly as a result of training (i.e., there was no transfer of training). The third and final year of the effort will involve similar studies of visualization and number-facility abilities. An important addition to the visualization study will be the use of two quite different criterion tasks in order to assess the generality of transfer. Funding: ONR

Report:

Levine, J.M., Brahlek, R.E., Eisner, E.J., & Fleishman, E.A., *Trainability of abilities: training and transfer of abilities related to electronic fault-finding* (Tech. Rep. 78-2). Advanced Research Resources Organization, March 1979.

#### **MECHANISMS OF SIMULTANEOUS LEARNING NR 154-424**

Northwestern/Underwood

The nature of human memory has been studied intensively in circumstances involving a single task. Normal training environments, however, generally require individuals to learn and perform a variety of tasks, switching among them on schedules that are frequently irregular. This planned two-year research effort is concerned with determining the generalizability of known laws governing human memory to situations in which multiple tasks are being learned simultaneously. There are two main aspects of this research. First, one must specify the parameters for transfer of learning to multi-task situations from tasks initially learned in isolation. Second, one must examine the sharing of learning and memory resources in situations in which tasks of different difficulties are being learned simultaneously. In investigating the simultaneous learning of tasks, this research can suggest principles for developing training materials and for managing their use in a complex training

environment. Experiments completed in the first year have focused on the nature and causes of interference which occurs when tasks learned in isolation are later encountered in a multiple-task setting. While these early experiments were intended primarily to replicate and extend previous findings, the results are both inconsistent and puzzling. At this point, these results serve to underscore the primitive nature of our understanding of the workings of human memory when multiple tasks are involved, and to motivate a further sorting out of this puzzle. Funding: ONR

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The following work units in this cluster were completed during the past year.

#### **AN INTEGRATIVE REVIEW OF RECENT RESEARCH ON INDIVIDUAL DIFFERENCES IN COGNITIVE PERFORMANCE**

**NR 150-406**

University of North Carolina/Carroll

This contract involved three reports on individual differences in cognitive function. The first (Carroll, 1978) pointed to the many methodological difficulties (e.g., sample size and characteristics, factor-analytic techniques) in establishing clear relations between psychometrically defined traits and the parameters of cognitive performances that have been studied experimentally. It also raised questions about the theoretical interpretation of these relations even if they can be firmly established. The second report was published as a review chapter in the *Annual Review of Psychology* (Carroll & Maxwell, 1979), covering recent research in individual differences in cognitive abilities under the following topics: traits, processes, and competence phenomena in cognitive psychology; studies of broad ability domains (standardized intelligence tests, factor-analytic studies of abilities, learning-ability relations); abilities in particular domains (such as language, creativity and fluency, thinking, perception, memory, and cognitive speed); cognition and personality; changes in abilities over the life span (from childhood to old age); genetic and environmental influences; and applied differential psychology (including studies of the determinants of school achievement).

Attention was focused on the implications of cognitive psychology for the study of individual differences. It was concluded that, although the new approaches are promising, this promise has not yet been fulfilled. The third (and final) report, still in preparation, but expected to be completed by December 1979, is to be a considerably expanded version of those portions of the *Annual Review* chapter that deal with relations between cognitive psychology and psychometric approaches. It will include detailed analyses (and, in some cases, reanalyses) and comparisons of various recent studies, many conducted under ONR sponsorship. It will make suggestions concerning future directions for research, including methods of taking account of differences in performance arising from variations in subjects' strategies in dealing with cognitive tasks. Subsidiary activities under this contract resulted in two other publications, one (Malmi, Underwood & Carroll, 1979) involving further analysis of data developed by Underwood (under a recently completed ONR contract), and the other (Carroll, 1979) presenting general comments on aptitude-process analysis studies by Snow (see NR 154-376 in this cluster) and others. Funding: ONR

See ARCHIVAL PUBLICATIONS: Carroll, 1978; Carroll, 1979; Carroll, in press; Malmi, Underwood & Carroll, 1979.

#### **INDIVIDUAL DIFFERENCES IN COGNITIVE PROCESSING NR 154-378**

Duke University/Day

Some individuals appear to be language-bound (LB) since they tend to perceive and remember events in language terms. Others are language-optional (LO) since they can use language rules or set them aside, depending on the nature of the task at hand. These two types of individuals first emerged in detailed studies of speech perception. Since then, reliable differences between LBs and LOs have emerged in a variety of cognitive tasks, including short-term memory, long-term memory, language translation, and visual scanning. Other studies demonstrated that these differences are not based on sensory or perceptual deficits, intelligence, or other artifacts. Instead, from the findings of this four-year effort, it appears that LBs

and LOs possess qualitatively different patterns of general cognition. These patterns apparently guide perception and memory in the everyday world as well as in the laboratory; for example, LBs have more trouble remembering a phone number after hearing it for the first time, but are better to remember jokes, especially if they are based on a linguistic core, such as a pun. It is clear that LBs are "bound" by language structure in a wide variety of situations; but is it language per se that binds them, or can any rich and complex system exert a similar effect? In order to examine this question, current research involves the use of music in perception and memory experiments. Preliminary evidence in this domain suggests that LBs are less able to perform a variety of music tasks, although the results are influenced by the nature of the melodies (e.g., lyrical vs. nonlyrical) and the level of processing required (e.g., listening for a particular instrument vs. an overall melodic pattern). Professional musicians have been examined in these experiments, as well as college students. Other recent work on the LB phenomenon includes refinements in the methods used to classify individuals as LB or LO, determination of the relative proportion of LBs and LOs in various populations (e.g., college students, business managers, elderly people, and musicians), comparison of various biographical data for the two groups, and experiments on letter and word search. A book describing the LB phenomenon based on experiments with over a thousand subjects in nearing completion, and a final report summarizing the work to date is in preparation. Funding: ONR

Reports:

See ARCHIVAL PUBLICATIONS: Day, 1979; Day, in press.

**INDIVIDUAL DIFFERENCES AND PERFORMANCE ASSESSMENT IN PERSONNEL MANAGEMENT—AN INFORMATION PROCESSING APPROACH NR 150-391**  
American Institutes for Research/Rose

This recently completed three-year effort was designed to refine, elaborate, and empirically validate an experimental test battery which could be used as a research or performance assessment instrument. Three major laboratory studies were

conducted, each study consisting of several cognitive tasks. In all, some 22 paradigms were evaluated. Individuals were characterized in terms of parameter values derived from the information-processing models of each task; and these parameters were evaluated with respect to their utility as components of a performance-assessment instrument. A further analysis attempted to isolate a set of cognitive operations, such as encoding, retrieval, and transformation. The general conclusions are that: (1) the existing test battery is logistically feasible for practical testing applications in terms of equipment requirements, time considerations, and test procedures; (2) within the constraints of sample sizes and theoretical orientations, these tasks meet acceptable criteria of reliability and construct validity. The primary implication of this research is that this test battery could be potentially predictive of performance on a wide variety of real-world tasks. As such, the battery could represent a significant advance over standard personnel assessment instruments and could promote increased understanding of the cognitive operations involved in any criterion task shown to be related to constructs in the test battery. The final report, cited below, reviews the entire effort. Funding: ONR

Reports:

Fernandes, K., Rose, A.M. An information processing approach to performance assessment: II. An investigation of encoding and retrieval processes in memory (Tech. Rep. 2). American Institutes for Research, November 1978. (AD A062826)

Allen, T.W., Rose, A.M., & Kramer, L.J. An information processing approach to performance assessment: III. An elaboration and refinement of an information processing performance battery (Tech. Rep. 3). American Institutes for Research, November 1978. (AD A062827)

Rose, A.M. An information processing approach to performance assessment (Final Rep.). American Institutes for Research, November, 1978. (AD A063010)

**APTITUDES AND INSTRUCTIONAL METHODS: INDIVIDUAL DIFFERENCES IN LEARNING-RELATED PROCESSES NR 154-376**  
Stanford University/Snow

This research was aimed at a theory of aptitude that (1) represents the abilities measured by apti-

tude tests in terms of the information-processing involved in the tests; and (2) relates this information processing to the effects of instruction on individuals of varying aptitudes. Such a theory thus offers an information-processing account of aptitude-treatment interactions. To achieve these aims, high school and college students were administered an extensive aptitude-reference battery when this research began. All subsequent experimental data were gathered on these students, and related back, as appropriate, to their original aptitude measures. Research on the first aim concentrated on laboratory studies of information processing in such tests as paper folding and verbal and geometric analogies. Analyses of eye movements and subjective reports indicate that successful, high-aptitude processing is characterized by a two-stage process which first constructs the correct answer to an item and then searches the response alternatives for the answer. Less successful, low-aptitude processing is characterized by less systematic, parallel processing of both item stems and responses. Other laboratory experiments on spatial construction and rotation problems, and on verbal comprehension, added the finding that speed of solving simple problems is psychologically independent of power of solving complex problems. Research on the second aim is

best represented by a study which related aptitude to a variety of learning measures taken during a computer-based course in computer programming. Fluid and visual intelligence, as well as a personality variable, independence, were strongly related to a variety of measures taken during and after the course. Another instructional study with other content supported the hypothesis that the relation of intelligence measures to learning outcome is based on differences in the information-processing demands placed on learners by alternative instructional treatments. High-aptitude learners appear more adaptive in meeting these demands than do low-aptitude learners. Taken as a whole, this research indicates that strategic flexibility may play a greater role in aptitude and learning than was previously suspected. A final report discussing this and other conclusions, and summarizing the three-years of research, is in preparation. Work building on the findings of this contract is being undertaken as part of a new effort by Snow (see NR 154-426 in this cluster). Funding: ONR, DARPA

#### Reports:

See ARCHIVAL PUBLICATIONS: Snow, 1978; Snow, 1979; Snow, Federico & Montague, in press.

### C. INSTRUCTIONAL THEORY AND ADVANCED TRAINING SYSTEMS

The work in this cluster is concerned with developing psychological theories of learning, performance, and instruction and exploring their implications for the design of advanced, computer-based training systems. (In prior editions of this booklet, this cluster was termed "Representing Knowledge for Training.") A continuing focus is on how to individualize instruction using the information that can be gathered as a student progresses through a course. This question is addressed largely through the study of experimental systems that dynamically generate instructional decisions and materials. Such systems require: (a) an internal representation of the knowledge and skills to be transferred to the student, (b) computational models of human performance and learning processes, and (c) computational models of instructional strategies that decide what to teach and how to teach it. (It should be noted that the research described in Cluster D, Cognitive Processes, is expected to provide crucial input to this cluster through analysis of the relationships between the structure of human knowledge and performance of complex tasks.) This research continues to address two important questions: (a) how to interpret indirect evidence from performance on exercises to infer a student's underlying knowledge, and (b) how to structure and sequence explanations, examples, and exercises to effectively build on this inferred knowledge state. Recent and new efforts to answer these questions focus on the potential advantages of *rule-based* knowledge representations for computer-based instructional systems. Rule-based representations are sets of "if---then" rules that express the relationships between conditions and actions appropriate to those conditions. Research on rule-based representations in the context of other work in the field of artificial intelligence has demonstrated several attributes that seem valuable in instructional contexts, especially the ability to use a single representation

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for several purposes within a system. (Rule-based representations are also particularly effective for representing *procedural knowledge*, or knowledge about how to do things.) The focus on such systems reflects a trend in this cluster to emphasize issues related to the training of skills rather than the teaching of static facts. Thus, plans for the cluster include research on the instructional capabilities of simulators used to train cognitive skills. Of special interest are simulations of tasks that are paced by external events, which require a high degree of control and coordination of cognitive skills. These tasks are important not only because they often have critical outcomes in the real world, but because our understanding of how they are performed and learned will contribute greatly to our knowledge of human capabilities.

Some of the efforts described below are supported jointly by the Office of Naval Research and the Cybernetics Technology Office of the Defense Advanced Research Projects Agency (DARPA). To coordinate work in this area, we have been holding annual meetings for the past six years, in which all the contractors informally brief each other on their latest work and plans. In addition, there are invited presentations by scientists outside the program who are working on related problems, as well as by military scientists investigating related, but more applied problems. Selected representatives of other cognizant Navy, DoD, and federal agencies are invited to attend the meetings and participate in the technical discussions. Coordination efforts in this domain have proven successful within the Navy. Current work at the Navy Personnel R&D Center (San Diego) is actively employing the products of earlier research in this area for the development of prototype training systems. In addition, during the past year, a structured coordination effort was begun with the Naval Training Equipment Center (Orlando) to transfer ONR-developed technology for generative, tutorial instruction into several projects there that are developing computer-based training simulators.

### **ANALYSIS OF TROUBLESHOOTING BEHAVIOR IN EQUIPMENT MAINTENANCE NR 154-435**

University of Southern California/Towne & Bond

As the technological complexity of Navy and Marine Corps hardware systems increases, the maintenance of those systems becomes a more crucial problem. For many years now, there has been considerable research on design for maintainability, maintenance aids, and training of maintenance technicians. ONR has supported research and training related to maintenance skills for a number of years (see NR 154-355 and NR 154-397 below). In this six-month contract, Towne and Bond are reviewing and integrating the widely scattered and interdisciplinary literature of reports and articles in maintenance training to provide information needed to plan further R&D efforts on (a) the selection and training of maintenance personnel; and (b) the required technology for advanced, computer-based maintenance-training systems. The focus of the review is on what is known about how technicians develop and use cognitive maps, or mental models, of the relationships among the parts of hardware systems. Issues being examined include individual

differences among trained technicians, inference-making from imprecise cognitive maps, implications of psychological research on memory for learning and using cognitive maps, and the implications of research in applied mathematics on the logic of diagnosis. Funding: ONR

### **TUTORING AND PROBLEM-SOLVING STRATEGIES IN INTELLIGENT COMPUTER-AIDED INSTRUCTION NR 154-436**

Stanford University/Buchanan & Clancey

This new work, planned to run for three years, builds upon earlier efforts (the most recent of which are those described for NR 157-387 and NR 154-379 below) to investigate techniques for representing knowledge and modeling learning and instructional processes. The aim is to provide individualized instruction via computer-based systems. The research examines the use of sophisticated, computer-based job-performance-aiding systems as "kernels" for instructional systems, and thus addresses the problem of how to acquire and represent the expert knowledge and skills underlying a domain of instruction. One focus is on the

development of the techniques needed to build a domain-independent tutorial system for teaching diagnostic methods. This system can be used with a variety of "expert" aiding programs which have in common a rule-based knowledge representation. During the first year, an experimental tutorial system called GUIDON is being implemented in the context of the MYCIN system, an operational interactive system that performs as an expert-level consultant to physicians diagnosing cases of bacterial infections. GUIDON is a case-method tutor which uses MYCIN's diagnostic rules and problem-solving procedures to maintain a model of a student's knowledge and diagnostic-reasoning abilities. It uses these models to select cases, and to structure and focus the explanations it presents in response to student queries and errors within a case. Research with the GUIDON system will include (a) study of the use of theoretical models of planning (e.g., like those being explored in NR 157-411 and NR 157-414 in the Cognitive Processing cluster), as they pertain to the planning for generation and execution of instructional dialogues; and (b) empirical evaluations of the effectiveness of different explanation strategies. GUIDON is being designed to serve as an instructional system for any expert program using the MYCIN rule-based architecture. Plans for the later years of this research, therefore, include an evaluation of GUIDON interacting with an expert system for diagnosing faults in electronic or mechanical systems. Funding: ONR, DARPA

**MODELING STUDENT ACQUISITION OF  
PROBLEM-SOLVING SKILLS NR 154-444**  
Rutgers University/Smith

Most scientific and technical instruction relies heavily on the use of examples and exercises to teach domain-relevant problem-solving skills. However, little is known about the relationship between the structure and content of such curricula and the learning abilities and strategies students must have for effective learning. For the most part, such curricula evolve through slow, unsystematic empirical evaluations. This new effort (planned to run for two years) will explore how learning from examples and exercises occurs. The approach is one of developing a computer-simulation model of a prototypical student which will learn logical proof procedures. The work will

make use of a specially developed computer-processable version of an existing curriculum of examples and exercises from a computer-based instructional system for logic. This curriculum has evolved over many years, and its content and structure are an implicit representation of effective pedagogical techniques. The simulation-oriented research will allow a more explicit understanding of these techniques. A particular focus will be on how students identify pedagogical strategies and use them to determine what to learn from a series of examples and exercises. One idea to be explored here is that a sequence of examples serves to illustrate a plan for solving problems in a domain, as well as to provide the necessary information to learn to recognize when that type of plan is applicable to a problem. After initial development of the simulation with the existing curriculum, experiments will be conducted in which the simulation will be used to predict how changes to the curriculum should affect learning of problem-solving procedures. The research has implications for the overall design of curriculum and of techniques for adaptive sequencing of exercises and examples in computer-based instructional systems. In addition, it will describe the knowledge required to implement tutorial explanations of strategies for effective learning. Funding: ONR

**A MODEL FOR PROCEDURAL LEARNING  
NR 154-399**  
Carnegie-Mellon University/Anderson

This three-year effort, scheduled to end by October, 1980, centers on developing a comprehensive model for the learning of skills and procedures, as contrasted to the learning of facts. The model, and a corresponding computer simulation known as ACT, tries to create a uniform theoretical framework for organizing our understanding of information-processing operations such as learning, memory, reasoning, and problem solving. ACT focuses on mechanisms of learning and has implications for designing instructional techniques. By building his theory of procedural learning into an existing theory of how people learn facts and relations, Anderson can represent both facts about the world and procedures that make use of these facts. The model represents factual knowledge in a semantic network which consists of

concepts and their interrelationships. Procedural knowledge is represented as a *production system*, a theoretical device which specifies which actions an individual will take under particular conditions or states of knowledge. To account for procedural learning, Anderson proposes a mechanism for sensibly modifying and varying the production system, as well as a mechanism which strengthens those variations found to be more successful in the light of experience. Among other capabilities, ACT is able to simulate such complex mechanisms as the generalization of learning and the optimization and automatization of cognitive procedures. The theory is being evaluated by simulations of people's learning of computer programming, mental arithmetic, and pattern recognition. Another context in which the theory is being evaluated involves the learning of geometry problem solving based on an analysis provided under a related investigation (NR 157-408) in the next cluster (D. Cognitive Processing). Experimental research with human subjects has evaluated predictions of the ACT model. These experiments have primarily considered how conditions of practice and attention influence the strengthening and optimization of procedures. Results suggest that learning principles derived from studies of fact learning may generalize more than expected to the learning of procedures. Funding: ONR

#### Reports:

Anderson, J. R., Kline, P. J., & Beasley, C. M. Jr. Complex learning processes (Tech. Rep. 78-1). Carnegie Mellon University, July 1978.

Anderson, J. R., Kline, P. J., & Beasley, C. M. Jr. A general learning theory and its application to schema abstractions (Tech. Rep. 78-2). Carnegie Mellon University, December 1978.

See also ARCHIVAL PUBLICATIONS: Anderson & Kline, 1979; Anderson, Kline & Beasley, in press; Anderson, Kline & Beasley, 1980.

The following work units in this cluster were completed during the past year.

### PSYCHOLOGICAL STUDY OF THE PRINCIPLES OF LEARNING AND TEACHING NR 154-387

University of California, SD/Norman

The goal of this research was to increase knowledge about the psychological mechanisms involved in learning and teaching complex materials. One focus was the investigation of fundamental principles of instruction; the other major focus was the development of operational computer-based tutorial systems to be used as testbeds for the study of these principles and as prototypes for potential applications. Several computer-based tutorial approaches were explored. One was a completely automated tutorial system for teaching such topics as computer programming. It used a semantic memory representation of the subject matter and of the student's knowledge of it. Another was a semi-automated tutorial technique which used a state-dependent teaching strategy, allowing for intelligent instruction on the part of the automated tutor where that was feasible. When necessary, the system called in a human tutor and presented an analysis of the student's problem, including a current model of the student's state of knowledge. Theoretical work concentrated on two aspects of learning. First, learning is not a homogeneous process, and several different forms of activity are involved. Second, the role of prior knowledge is critical, and students must be presented with appropriate conceptualizations and metaphors for proper understanding of the new knowledge they are acquiring. The work included the development of an experimental minicomputer system which dynamically tracked and analyzed the pattern of each student's access, in a computer-assisted learning context, to instructional material. A summary of this three-year effort appears in the final report, listed below. Funding: ONR, DARPA

#### Reports:

Williams, M.D. The process of retrieval from very long term memory (Tech. Rep. 7801). University of California, September, 1978. (AD A060327)

Miyake, N., Norman, D.A. To ask a question, one must know enough to know what is not known (Tech. Rep. 7802). University of California, November 1978. (AD A063309)

Bott, R. A. A study of complex learning: Theory and methodologies (Tech. Rep. ONR 7901). University of California, March 1979. (AD A068323)

Norman, D. Studies of learning and self-contained educational systems, 1976-1979 (Tech. Rep. 7902, Final Rep.). University of California, June 1979. (AD A071027)



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See also ARCHIVAL PUBLICATIONS Gentner, 1979; Miyake & Norman, in press; Norman, 1978 (a), (b); Norman, 1979; Norman, in press (a), (b), (c), (d), (e), (f); Norman & Bobrow, 1979; Norman & Gentner, 1978; Rumelhart & Norman, 1978.

### IMPROVING THE ACQUISITION AND UTILIZATION OF SKILLS RELEVANT TO NAVY TECHNICAL TRAINING NR 154-355

University of Southern California/Rigney

This effort, which ended in December, 1978, was concerned with improving the effectiveness of training by investigating the theoretical and empirical bases of instruction. The work emphasized improving instructional systems. Theoretical studies focused on schema-theory descriptions of cognitive processes, strategies for extracting logical relationships from written discourse, electrophysiological correlates of cognitive processing, and the effects of different text structures on summaries and recall. Empirical investigations focused on the development of a computer-based generalized maintenance training system, GMTS, for hands-on troubleshooting training. GMTS was field tested using the fleet communications system for systems-level troubleshooting practice (see Technical Report 89), and using the AN/SPA-66 radar repeater for modular-level troubleshooting (Technical Report 90). This research has since entered a prototype development stage under joint funding from the Navy Personnel Research and Development Center and the Defense Advanced Research Projects Agency. The new system will be applied in a Navy class-C school on WSC-3 equipment. Consideration is being given to using the system in Navy class A-school applications as well. Funding: ONR, DARPA

#### Reports

Williams, L. A., Rigney, J. W. Electrophysiological correlates of cognitive activity: Event-related slow-potentials developed during solution of anagrams (Tech. Rep. 86) University of Southern California, July 1978 (AD A059044)

Bond, N. A., Jr., McGregor, D., Schmidt, K., Lattimore, M., & Rigney, J. W. Studies of verbal problem solving: II. Prediction of performance from sentence-processing scores (Tech. Rep. 87) University of Southern California, June 1978 (AD A060075)

Rigney, J. W., Towne, D. M., King, C. A., & Moran, P. J. Field evaluation of the generalized maintenance trainer-simulator I. Fleet communications system (Tech. Rep. 89) University of Southern California, October 1978 (AD A061451)

Rigney, J. W., Towne, D. M., Moran, P. J., & Mishler, R. A. Field evaluation of the generalized maintenance trainer-simulator: II. AN/SPA-66 radar repeater (Tech. Rep. 90) University of Southern California, November 1978.

Towne, D. M., Munro, A., & Crook, D. E. Research on learning strategies and hands-on training in CAI (Final Rep.) University of Southern California, November 1978 (AD A064176)

### SELF-DIRECTED LEARNING TO MEET JOB-PERFORMANCE REQUIREMENTS NR 154-397

University of Southern California/Rigney

Military tasks, such as troubleshooting complex electronics equipment, often require the use of texts, such as technical manuals. Such texts are not organized for instructional purposes and, typically, far more information is available than is needed for accomplishment of a particular task at hand. This effort was designed to develop a computer-based instructional system to teach self-directed, selective reading skills for learning from job-related texts. The approach was to develop a computer program, on a PLATO IV computer system, that provides automated aids to this kind of self-directed learning. One of the functions of this aids system is to prompt careful task analysis, including the formulation of reading objectives relevant to the job task at hand. Another function is to permit the student/user to create a task-specific list of portions of the text, and to require that these be related by the student to specific objectives. The structures of the aids system are designed to promote conceptually-driven processing in the use of texts in job-related tasks. Experimental tests of the training system found consistent (but statistically nonsignificant) advantages for users of the aids system on measures of effective learning, selective learning, and planning. The second goal of the research effort was to discover structural and procedural differences in students' understanding of different types of texts. Previous research has concentrated on narrative, story-like texts. The techniques of this type of cognitive research on text processing were modified and applied to types of texts more likely to appear in technical and instructional documents. In addition to stories, instructions and definitions were also studied. Results of a series of experiments on text similarity and memory for text content suggest that text type is an important psycho-

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logical variable. One result suggests a possible interaction between text-processing strategy and success in learning from different types of texts. The final report, shown below, reviews highlights of the entire effort. Funding: DARPA

### Reports:

Crook, D.E., Munro, A., Rigney, J.W. & Lutz, K.A. A computer-based training system for selective text processing (Tech. Rep. 88). University of Southern California, August 1978. (AD A060036)

Munro, A., Lutz, K. A. & Gordon, I. On the psychological reality of text types (Tech. Rep. 91). University of Southern California, February 1979. (AD A067791)

Munro, A. & Towne, D.M. Research on self-directed learning to meet job performance requirements (Final Rep.). University of Southern California, February 1979. (AD A067780)

See also ARCHIVAL PUBLICATIONS. Munro, in press, Rigney & Munro, 1979, Rigney, Lutz & Crook, in press.

### TEACHING CAUSAL KNOWLEDGE AND REASONING BY COMPUTER NR 154-379

Bolt Beranek and Newman/Collins

Future instructional systems in the Navy and Marine Corps can be enhanced by effective techniques for generative computer-assisted instruction (CAI), that is, CAI which generates instruction on-line from a data base which represents the subject matter to be taught. This three-year effort (1) developed a computational theory of tutoring causal knowledge and reasoning, (2) implemented that theory in a rule-based formalism in a genera-

tive CAI system (the WHY System), which carries on a dialog with students on meteorology concepts; and (3) used the system to evaluate the relative effectiveness of different tutoring strategies. The theory of tutoring was developed through the analysis of dialogues involving human tutors and by experiments with students. It specifies (1) strategies for generating questions in different situations; (2) goals that tutors pursue and the priorities assigned to different goals; and (3) the misconceptions students have and how tutors identify and correct them. Experiments with the Why system investigated the effects of alternative strategies and goal priorities on the structure of dialogs. The work done on students' misconceptions in reasoning about causal systems has led to a new effort focusing on that problem (see NR 154-428 in the Cognitive Processing cluster). Funding: ONR, DARPA

### Reports:

Collins, A. Explicating the tacit knowledge in teaching and learning (Tech. Rep. 3889). Bolt Beranek & Newman, March 1978. (AD A058741)

Stevens, A.L., Collins, A. Multiple conceptual models of a complex system (Tech. Rep. 3923). Bolt Beranek & Newman, August 1978. (AD A063073)

Bates, M., Brown, G., & Collins, A. Socratic teaching of causal knowledge and reasoning (Final Rep. 3995). Bolt Beranek & Newman, December 1978.

See also ARCHIVAL PUBLICATIONS. Stevens, Collins & Goldin, 1979, Stevens & Collins, in press, Bates, Brown, & Collins, 1979, Brown, Collins & Harris, 1978, Reichman, 1978.

## D. COGNITIVE PROCESSING

This program is aimed at characterizing skilled performance in real-world tasks which demand complex information processing. Map interpretation, troubleshooting, and military intelligence analysis are three of the many possible examples of such tasks in the Navy. Expertise in these kinds of tasks is often restricted to small numbers of "exceptional" individuals. It is also acquired with considerable difficulty and after long post-instruction experience. Furthermore, the cognitive processes involved in these tasks are commonly unavailable to the consciousness of an expert, so that explicit accounts of these processes are not available for instruction of novices or for other purposes. Demands for high levels of expertise are increasing in the Navy along with the pressures on training at the same time that the manpower pool is decreasing. This research will provide explicit formal theories of crucial cognitive components of required skills. These theories will constitute the foundations for selection of individuals with expert potential, training methods which can shorten the time now required for skill development, and personnel-evaluation techniques for assessing the extent of an individual's level of expertise.

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The content of the research in this cluster is addressed to four basic aspects of skilled cognitive processing:

- the process of information collection and analysis;
- the representation of task domains in novice and expert problem solvers;
- human planning processes, and
- features of complex skilled action such as coordination, control, and error recovery.

The general approach of the research is to build models of skilled problem solving which directly represent the relevant cognitive processes and structures. In addition, these models will have parameters which reflect the characteristics of the individual problem solver, his or her training history, and the problem-solving environment.

The second contractors' meeting in this area was held in Cambridge, Massachusetts, in June 1979. These meetings featured presentations of the work described below and of related applied work at the Navy Personnel R&D Center. The Air Force Office of Scientific Research also provided a presentation of their related basic research in flight and technical training. Some of the research in this cluster is funded by DARPA's Cybernetics Technology Office, spurred by their interest in developing advanced technology for the acquisition and maintenance of skills. Additional coordination of this area is effected with DARPA and AFOSR through frequent, regular meetings with the relevant research managers.

### TOPIC AND THEME IDENTIFICATION IN PROSE COMPREHENSION NR 157-423

University of Arizona/Kieras

This work unit (in its second of a planned three years), and the one following (NR 157-422), are both investigating selected aspects of text comprehension for purposes such as military intelligence analysis and troubleshooting. Most, if not all, jobs involving text comprehension require that the reader first determine the topic or subject of the material being read. This is done, at the least, to decide whether this material is relevant and, more importantly, to allow the reader to identify the overall context required for deeper comprehension. This research first determined what superficial, or surface-level, features of a text influence the readers's perception of the subject matter by having them identify the topics of passages which varied in the superficial linguistic devices used to signal the topics. While these signals are effective, it was found that readers can select thematic information from the meaning content of the passages very efficiently, and in spite of conflicting superficial signals. Their choices appear to be consistent with van Dijk's rules for generating the abstracted content, or macrostructure, of a passage. These meaning-based processes will be

studied in more detail experimentally to determine the roles played by the specific passage content and the reader's background knowledge in governing the application of the macro-structure generating rules. The results will be incorporated into a simulation model of the strategies for using the various thematic signals and the macro-structure rules. The model is based on Anderson's ACT system, van Dijk's linguistic analysis of text structure, and Kintsch's theory of text comprehension. It will be evaluated with behavioral data and then applied as a tool for describing topic-identification strategies and for training efficient topic extraction. Funding: ONR

#### Reports

Kieras, D.E., The relation of topics and themes in naturally occurring technical paragraphs (Tech. Rep. 1). University of Arizona, January 1979.

Keiras, D.E., Modelling reading times in different reading tasks with a simulation model of comprehension (Tech. Rep. 2). University of Arizona, March, 1979.

### COMPREHENSION AND ANALYSIS OF INFORMATION IN TEXT NR 157-422

University of Colorado/Bourne & Kintsch

This three-year research effort, like that described above (NR 157-423), is concerned with text

comprehension, but is focused on the process whereby appropriate text-derived inferences are incorporated into the reader's representation of the task domain. One case of this might be in military intelligence analysis, where the analyst must determine the relevance and implications of each message for each of a number of issues which are his concern. An analogous situation, more amenable to research, forms the main paradigm of this work. This situation concerns a market analyst who must make recommendations concerning the behavior of stocks and other investments on the basis of inferences derived from reports, newspaper stories, and other bodies of text. The theoretical approach taken to this problem is a combination of Bourne's view of concept learning and Kintsch's theory of text comprehension. The latter theory allows one to tell how and how well people are able to decompose a text into a set of propositions which represent its meaning. These propositions form the input to the concept-learning theory, which describes how people use experience to learn which types of information (profits, management reports, etc.) are predictive of the value of each stock under consideration. In the first year, just completed, a set of prose materials was developed from which one can generate stock-market reports with known decision-relevant properties. These materials were used in experiments investigating the memorial consequences of reading brief market reports and making decisions based upon them. Learning to make the right decisions was found to be accompanied by a memory enhancement of the decision-relevant portions of the text. These memory results are being used to construct a detailed model of how the decision-relevant information is extracted in information-analysis tasks. Funding: ONR

Report:

Kozminsky, E., Bourne, L.E. Jr., & Kintsch, W. Comprehension and analysis of information in text: I. Construction and evaluation of brief texts (Tech. Rep. 79-1). University of Colorado, July 1979.

**FORMAL AND INFORMAL REASONING IN PROBLEM SOLVING NR 157-408**  
University of Pittsburgh/Greeno

This work, like that described in the following five contracts, is concerned with the perceptual and

cognitive representations of task domains that underlie performance in those domains. Much of the work in these contracts is also concerned with the role of external graphic and perceptual aids such as diagrams, maps, and schematics. Greeno's research (now in the second of a planned three years) is concerned with the relationship of the syntactic or formal properties of a domain to the semantic properties (those that relate the domain to real-world experience). His investigations have focused on a prototypical case, plane geometry, where the distinction between syntactic and semantic processing seems particularly sharp. The syntactic properties are contained in the axioms and theorems of the system, and the semantic properties are represented by diagrams and other properties of geometric constructions as they appear in the real world. Progress during the past year included development of a formal representation of spatial inferences made in solving geometry problems. A detailed simulation model that Greeno has developed represents knowledge of strategies and perceptual concepts along with procedures for making inferences of the kind we now can describe formally. Another development was the analysis of a task primarily consisting of formal reasoning: the checking of proofs. Human performance was found to be deficient on this task, and theoretical analysis of the task requirements indicated that humans lacked an adequate procedure for testing the sufficiency of assertions in the grounds for inferences. A hypothesis about the nature of the appropriate cognitive structures will be tested in a study in which subjects trained to check proofs will be given tasks designed to reveal their understanding of the formal structure of the problem domain. A programming language for geometric constructions has been developed and is being used to study characteristics of complex spatial cognition. Studies measuring the time required for judgments about diagrams are providing data on the ability of humans to use redundant characteristics in processing spatial information. Funding: ONR

**EXPERTISE AND SKILLED PERFORMANCE IN ANALYTICAL AND PERCEPTUAL PROBLEM SOLVING NR 157-421**  
University of Pittsburgh/Glaser & Chi

This work is addressed to the full spectrum of differences between expert and novice problem

solvers. Planned to run for five years, the effort (now starting its second year) concentrates at present on how experts differ from novices in their representations of particular problems. Two classes of problems are being considered: Analytical problems are studied within the context of physics problem solving, whereas perceptual problems are studied in the context of map interpretation and use. Initial studies on analytical problem solving were designed to determine the nature of the representations used by experts and novices. Experts tended to use a deeper level of representation, such as the principles underlying a physics problem, whereas novices tended to use a surface representation, such as the visual diagram. Work will continue to study the characteristics or features of physics problems that elicit these different levels of representations in the experts and novices, as well as the relationship between these representations and problem solutions. Concurrently, studies are also being carried out on the specific knowledge that experts have in excess of knowledge possessed by the novices. Attempts will be made to identify the relationship between knowledge and success at finding the correct solution paths. Research on perceptual problem solving began with the question of identifying the components involved in expert map reading. (See NR 157-410 and NR 157-416 below for related work.) Large-scale studies have been carried out on the relationships between self-ratings of map-using abilities, short-term memory tasks (such as memory for maps after a brief display), and map-reading tasks (such as finding routes on a map). Memory for maps can provide information about the user's cognitive representations of maps. A primary concern here is to determine the relationship between cognitive representation and actual map usage. Attempts are also being made to determine whether map-reading task performances are predictable from spatial/reasoning abilities, as measured by psychometric tests. Further studies are designed to isolate the processes and abilities which experienced navigators and vehicle drivers use to find routes and locations. These studies will relate performance on map using to the actual performance of orienteering and locating routes in the field. Funding: ONR

Reports

See ARCHIVAL PUBLICATIONS. Chase, in press; Chi & Glaser, in press

#### **COGNITIVE AND INSTRUCTIONAL FACTORS IN THE ACQUISITION AND MAINTENANCE OF SKILLS NR 157-430**

University of Pittsburgh/Glaser & Lesgold

This effort investigates the psychological characteristics and instructional requirements involved in attaining high levels of proficiency. It considers the kind of learning required for various professions and skilled trades in which hundreds or thousands of hours of instruction and apprenticeship are often required. Past studies of skill acquisition appear to have devoted too much attention to short-term learning and to early phases of instruction. More knowledge is required about the nature of and conditions that lead to advanced levels of competence and expertise. Such knowledge should enable us to devise instructional strategies and training systems that produce fewer failures of learning or retention, higher levels of skill attainment, and maximal transfer to new situations. The explicit goal of the research is to identify the knowledge structures and information-processing strategies that characterize expertise and advanced competence, and to develop an instructional psychology of long-term learning that is grounded in extensions of current cognitive psychology. Work toward this goal requires attention to the analysis of skilled performance, the analysis of lesser levels of competence, the conditions that promote transition from lower to higher levels, and related problems of cognitive theory and methodology. Each of these component problems is being investigated in domains of instruction that are representative of the wide range of training programs in which the military is engaged. The work consists of five sub projects: (a) Spatial Visualization Abilities in Technical Skills; (b) Learning of Perceptually Complex Diagnostic Problem Solving Skills; (c) Skill in the Management of Active Memory; (d) The Influence of Existing Knowledge on Learning; and (e) General Principles of Skilled Performance and its Acquisition, dealing primarily with mathematical skills. Funding: DARPA

#### **KNOWLEDGE ACQUISITION AND PERFORMANCE MODELS FOR SPATIAL AND LOCATIONAL COGNITION NR 157-410**

Rand Corporation/Thorndyke

This work is primarily concerned with spatial cognition and knowledge acquisition. The research, in

its second of a planned three-year span, is addressed to four issues: map learning, spatial-knowledge acquisition through navigational experience, individual differences in spatial-knowledge acquisition, and distance estimation. Several studies on map learning gathered detailed verbal protocols from subjects learning maps over several trials. Analyses of these data indicate that individual differences in map-learning skill may be attributable to learning strategies (i.e., subjects' approach to the learning task) and to individual study procedures (e.g., systematic sampling of information, imaginal coding of spatial information, evaluation of learning progress, etc.). Subsequent studies have demonstrated that learning success may be predicted from psychometric tests of visual-memory ability and field independence. In addition, training subjects to use effective study procedures significantly improves the performance of all but the lowest spatial-ability subjects. Research on spatial-knowledge acquisition through navigational experience has contrasted such knowledge of a locale with that acquired from studying a map of the locale. Studies on people with these different types of experience indicate that navigational experience leads to superior ability to orient oneself in the environment and to estimate route distances between points. Map learning, on the other hand, results in superior knowledge of global relations (relative locations and straight-line distances among objects). Further, while extensive navigational experience eventually induces knowledge of global relations, overlearning a map does not seem to improve orientation ability. Future studies will investigate the relationship between visual-memory ability and optimal modes of acquiring spatial knowledge. Distance-estimation studies have investigated the influence of path clutter on people's estimates of the distance along the path. Such clutter causes people to overestimate distances, both when estimates are made perceptually and when they are made from a memorized map. The similarity between perceptual and memorial data indicates that distance estimation in memory relies on a visual or imaginal process. Funding: ONR

#### Reports

Thorndyke, P.W., Stasz, C. Individual differences in knowledge acquisition from maps (Rand Rep 2375 ONR) The Rand Corporation, January 1979. (AD A065040)

Thorndyke, P., Stasz, C. *Training procedures for map learning* (Note-1018-ONR) The Rand Corporation, August 1979.

See also ARCHIVAL PUBLICATIONS: Thorndyke, 1979; Thorndyke & Stasz, 1979.

### HUMAN PLANNING AND PROBLEM SOLVING IN NAVIGATION NR 157-416

Bolt, Beranek and Newman/Stevens

This research represents a bridge between the work on representation described above and NR 157-414 & NR 157-411 (described below), which are addressed to planning. The work, expected to run for three years and now at its halfway mark, is aimed at a theory of route planning in a variety of environments ranging from cities to coastwide navigation scenarios. The theory takes the form of a planning grammar, a set of rules for expanding parts of a route plan in terms of a structured set of elements. The rules operate on a representation of the locale. The representation is characterized as an information network describing constraints on the spatial relationships of objects. Research during the past year has identified a set of planning rules and a set of basic types of constraints that people use in representing spatial information. When complete, the theory will represent various types of route plans (e.g., crow's flight, region to region), and will describe how people use various types of representation of the locale (e.g., routes, locations, etc.). Of particular interest will be the strengths and weaknesses of each type of plan vis-a-vis the different types of representation. Empirical evaluation of the theory will take place within the context of a computer-based simulator of a locale and movements within the locale, which allows subjects to plan and traverse routes in the locale without the constraints imposed by real-world route traversal. The result will be a high volume of data on route planning and selection which can be analyzed in terms of the theory. One such analysis will be an attempt to interpret particular planning errors in terms of the plans or subplans which produce those errors. Region-to-region plans, for example, may often choose longer-than-necessary routes; route-to-route plans may run into problems where the subroutes meet. Stevens is also attempting to define the common elements between route construction and construction geometry via an active collaboration with

Dr. James Greeno (see NR 157-408, above).  
Funding: ONR

#### **HUMAN UNDERSTANDING OF COMPLEX SYSTEMS NR 154-428**

Bolt Beranek & Newman/Collins

Boiler technicians, pilots and electronics technicians are among the many Navy and Marine Corps jobs which require an understanding of complex causal systems and an ability to predict their behavior under a wide variety of circumstances. This new three-year effort, which builds upon Collins' earlier work (see NR 154-379 in the previous cluster), seeks to formulate a theory of such understanding and its acquisition through training. The theory will make possible the development of training systems for giving personnel appropriate and powerful conceptions of complex systems, and teaching them how to choose the conception appropriate to particular tasks. To this end, Collins has established a collaborative relationship with an NPRDC project on automated training in steam-propulsion plants. The theoretical basis of the approach is the concept of a model, a psychological isomorph of a physical system which represents understanding of the system. The nature of these isomorphs will be determined for steam-propulsion systems, weather systems, etc. Studies using recall and other appropriate methods will be used to validate the isomorphism, and comparative evaluations of alternative training methods will be conducted. Funding: ONR, DARPA

#### **PROCEDURAL-NET THEORIES OF HUMAN PLANNING AND CONTROL NR 157-414**

Science Applications, Inc./Atwood

The goal of this work, now in the second year of a planned three, is to develop a theory of human planning in the context of software design. The form of the theory is a combination of ideas derived from procedural networks, which posit that planning occurs by successively (a) expanding each abstract part of a plan into more concrete subparts, and (b) ensuring appropriate coordination between the subparts and from "blackboard" models of knowledge representation which describe how the knowledge involved in planning is stored and used. (See the following description, NR 157-411.)

Empirical work on the theory currently consists of analyzing verbal protocols collected from experienced software designers, and exploratory experiments to examine the content and structure of expert designers' knowledge of planning in the context of software design. The findings will be used to select problems and methods for studying planning processes in more structured laboratory environments which allow for more automated data collection. Based on these resulting studies, simulation models of the planning process will be constructed. The set of techniques being developed in this effort will be used in a variety of ways: the order of expansion of the networks can be examined; the role of the planning medium (program design languages, flowcharts, etc.) can be investigated; the ways in which people combine design and planning knowledge with knowledge of the task or problem domain can be examined; and the effects and effectiveness of instruction in various design philosophies (e.g., top-down expansion) can be evaluated. Funding: ONR

Report:

Atwood, M.E., Polson, P.G., Jeffries, R., & Ramsey, H.R. Planning as a process of synthesis (Tech Rep 1). Science Applications, Inc., December 1978 (AD A064334)

#### **COGNITIVE PROCESSES IN PLANNING AND CONTROL NR 157-411**

Rand Corporation/Hayes-Roth

This effort, like 157-414 above, is concerned with human planning behavior. It has also now begun to explore the control aspect of planning, which involves the monitoring and guiding of a previously formed plan to a successful conclusion. The research centers on modeling the behavior of the individual planner and controller. The working model postulates that planning comprises a series of individual decisions which are generated by a variety of independent cognitive "specialists." Each specialist can make a particular type of contribution to the plan in progress whenever certain preconditions are met. Although the specialists operate independently, they all record their decisions in a central database, the "blackboard." This enables them to incorporate selected prior decisions in their own decision-making processes. Two kinds of research support this model of the planning process. First, the model has been imple-

mented as a computer program and its performance is comparable to the performance of human subjects. The simulation produces a planning protocol which includes the same kinds of decisions and decision sequences observed in human protocols. In addition, the simulation produces finished plans that closely resemble those produced by human subjects. Second, several experimental studies support the model's basic assumptions, including the following: (a) that decisions occur at several distinct levels of abstraction; (b) that individual decisions constrain subsequent decisions; (c) that early decisions suggest unanticipated opportunities for subsequent plan elaboration; and (d) that people can adopt alternative executive strategies for planning. Additional related studies have identified important task variables and sources of individual difference in planning skill. Work during the last fifteen months of this planned 3-year effort will focus on control of plan execution, and will include: (a) machine experiments to evaluate the costs and benefits of alternative executive strategies; (b) systematic investigations of selected task variables; (c) studies of the nature and sources of errors in judgment during planning; and (d) systematic studies of cognitive bases for individual differences in planning skill. Funding: ONR

## Report

Hayes-Roth, B., Hayes-Roth, F. *Cognitive processes in planning*. (Rand Rep. R-2366-ONR) Rand Corporation, December, 1978. (AD A058384)

See also ARCHIVAL PUBLICATIONS: Hayes-Roth, Hayes-Roth, Rosenschein & Cammarate, in press; Hayes-Roth, B., 1979; Hayes-Roth & Thorndyke, 1979.

### STUDIES OF SKILLED HUMAN PERFORMANCE NR 157-437

University of California, SD/Norman & Rumelhart

This recently initiated contract reflects the cluster's emerging concern with control and coordination of complex output processes. Skilled human performance will be studied in tasks where high-speed motor operations appear to be executed by numerous control functions operating in parallel. Transcription typing is a good example of such a task and will constitute one empirical focus of the work undertaken here. Other less constrained

tasks such as those mentioned in the contract described below (NR 157-434) will also be studied. Theoretical work will concentrate on a computer-simulation model of skilled performance. The model will be based on a loose hierarchy of control schemata acting in parallel. Each schema is seen as being activated by appropriate triggers from higher-level schemata, and such activation itself triggers lower-level schemata. The model will be able to predict error patterns, interresponse time distributions, and other observable aspects of skilled performance. In addition, special paradigms and tasks which selectively examine or load different components of the system will be used to provide more discriminating evidence for the model. Funding: ONR, DARPA

### APPLIED HUMAN INFORMATION PROCESSING: APPROXIMATE METHODS NR 157-434

University of California, SD/Norman & Rumelhart

This one-year effort explores the more applied aspects of the ideas on attentional control and coordination of cognitive structures discussed above (NR 157-431). The focus of the work is on certain errors made by highly skilled operators of complex, high-demand systems. A theory of action of the same type discussed above (i.e., a hierarchy of schemata acting in parallel) has provided an initial account and taxonomy of such errors. The account holds that these kinds of errors are due to the improper triggering of schemata responsible for initiating action sequences. In some cases, errors arise due to improper specification of one's original intention. The wrong switch may be closed, for example, when information to distinguish two similar switches is not passed to the relevant mental control structures. In other cases, errors arise when schemata are improperly activated or not activated when required. This occurs when components of one action sequence intrude into another action sequence because of a close association between the two in perception, memory or temporal occurrence. A third set of errors can be identified with improper triggering or sequencing of appropriate schemata. Examples of such errors are omission or repetition of checklist steps. The taxonomy (in a more detailed form) has been applied to several sources of post-hoc accounts of naturally occurring



errors. Plans call for further application to errors systematically observed in controlled settings such as flight simulators. These analyses will eventually

lead to principles for reducing the impact of human error through improved system design and operator training. Funding: DARPA

## E. ANALYZING JOB DEMANDS

Success in a job depends on a number of factors, such as aptitude for the job, mastery of the required knowledge and skills, motivation, the social and physical environment of the job, and its organizational context. Understanding the dimensions of jobs and their organizational dynamics help us to relate the attributes and demands of jobs and their contexts to personnel selection, training assignment and job-classification criteria. In recent years, we have been winding down our research under this cluster for two main reasons: (a) we believe that the technology of task and job analysis has matured sufficiently to be useful to those concerned with its application to actual Navy jobs; and b) the particular thrust of this cluster dealing with such variables as job design, job satisfaction and job-related causes of personnel attrition is now being pursued by the Organizational Effectiveness Research Programs under clusters K (Adaptation in Organizations) and M (Personnel Turnover & Retention). The work units described below, now completed, represent the last two efforts carried under this category. Both were aimed at increasing our knowledge of the factors affecting the complex interaction among abilities, job performance, and other aspects of the world of work. Until the last two years, when the number of contracts fell below a "critical mass," we coordinated work in this cluster by holding annual meetings of the contractors, augmented by attendees from other Navy, DoD and federal agencies.

The following work units in this cluster were completed during the past year.

### **ORGANIZATIONAL POLICY DECISIONS AS A FUNCTION OF TASK DESIGN AND INDIVIDUAL ABILITIES, PREFERENCES AND ORIENTATIONS NR 151-377** University of Akron/Barrett

The research has involved the development and validation of a Congruence Model of job design which allows for the prediction of productivity, work satisfaction, and tenure. The Congruence Model is based on an assumption that task, workers and organizational factors interact in a work situation. The model incorporates the variables of information-processing abilities, preferred job features (such as variety), individual expectations concerning the task (the job will have variety), and objective measures of the complexity of the task (such as number of decisions to be made). The Congruence Model has been supported in a series of field studies involving naval and civilian personnel, and laboratory studies which have simulated

monitoring, such as visual scanning of a radar-scope display. Results from a series of studies have pointed to the key role of information-processing abilities in influencing preferences for certain job attributes, in determining performance, and in job-satisfaction outcomes. In general, individuals with high levels of ability expressed preferences for jobs which include more variety. Specific information-processing abilities have been identified which relate positively to job performance in monitoring tasks, but negatively to job satisfaction. Thus individuals with the most task-related ability derive the least satisfaction from performing a monitoring task. The research project has developed computerized measures of information-processing ability (e.g., reaction time, short term memory, visual search) and computerized measures of task preferences and descriptions (e.g., response pace, stimulus variety and response variety). The major research finding is that computerized measures of information-processing ability relate to monitoring performance. In addition, computerized measures of information-processing preferences relate to task satisfaction. This leads to the conclusion that organizations can identify and specify the relationships among the variables in the Congruence Model by use of computerized

## PERSONNEL AND TRAINING RESEARCH PROGRAMS

measures, and can make selection and job-design policy decisions which will lead to more desirable outcomes for the organization and the individual. A final report, which will summarize the major findings of this four-year effort, is in preparation. Funding: ONR

### Report:

See ARCHIVAL PUBLICATIONS: Rush, Phillips & Panek, 1978.

### ENHANCING THE ABILITY-PERFORMANCE RELATIONSHIP: A STUDY OF SOME FACTORS AFFECTING TOTAL GROUP AND DIFFERENTIAL VALIDITY NR 151-375

University of Maryland/Schneider

The major purpose of this research was to develop ways of conceptualizing and studying the contribution of non-ability measures to the prediction of performance over and above predictions based on ability measures alone. Of primary interest were non-ability measures associated with the work situation. During the four years that this contract ran, a number of major conceptual/research projects were undertaken and a Selection Research Conference was held at the University of Maryland. The work concerned: (1) a study of the contribution of intrinsic task-reward characteristics to ability-performance relationships for bank clerks; (2) an exploration of the contribution of person (motivation)-situation fit to the prediction of performance based on only ability measures; (3) a laboratory study of the role of realistic task previews in the prediction of performance; and (4) a large-scale study of the way in which classroom characteristics contribute to the prediction of stu-

dent performance. The experimental findings, the Selection Research Conference, and a major review of the literature on ability-situation interactions, all seem to suggest that, in field settings, ability rarely is related to performance in *interaction* with situational variables, but that *both* ability and situation combine *linearly* to predict performance. The failure to find the expected significant algebraic interaction terms was surprising. These findings and data have been summarized in a series of technical reports, including one report with the proceedings of the Selection Research Conference. These proceedings were published in a single issue of *Personnel Psychology* (1978, 31). The final report, cited below, emphasizes the theoretical issues illuminated. Funding: ONR

### Reports:

Hoffman, R.G., Ability, involvement and climate as multiple and interactive predictors of performance (Tech. Rep. 21). University of Maryland, April 1979.

Hannan, R.L., Work performance as a function of the interaction of ability, work values, and the perceived work environment (Tech. Rep. 22). University of Maryland, April 1979.

Schneider, B., Parkington, J.J., & Mosier, S.B., Some relationships between the ability requirements and reward attributes of tasks (Tech. Rep. 23). University of Maryland, April 1979.

Katcher, B.L., Bartlett, C.J., Rating errors of inconsistency as a function of dimensionality of behavioral anchors (Tech. Rep. 24). University of Maryland, May 1979.

Schneider, B., Methodological and conceptual issues in understanding ability-performance relationships (Final Rep. 25). University of Maryland, April 1979.

See also ARCHIVAL PUBLICATIONS: Bartlett, Bobko, Mosier & Hannan, 1978; Guion, 1978; Locke, Mento & Katcher, 1978; Owens, 1978; Schein, 1978; Schmidt & Hunter, 1978; Schneider, 1978; Schneider & Dachler, 1978; Wanous, 1978.

## **MANPOWER R&D PROGRAMS**

### **[Clusters F-I]**

This is a program of exploratory development (6.2) with management responsibility vested in the Psychological Sciences Division but involving other disciplines within ONR as well. The program came into being (in 1973) as a direct result of the then-new national policy that replaced the draft with the all-volunteer force as a source of defense manpower. The ONR manpower program has dealt with a wide range of problems in both a reactive and an anticipatory mode. A major aim has been the development of techniques and models to be used by Navy and Marine Corps managers to deal with manpower and personnel issues. Research is conducted in universities and other institutions; methods are varied and include experimentation, statistical analysis, simulation, and modeling. There is a close coupling of this program and the operating arms of the Navy and Marine Corps through the mechanism of a planning committee, whose members include not only ONR scientific officers but also representatives of the Naval Material Command, the Bureau of Naval Personnel, the Navy Recruiting Command, the Navy Personnel Research and Development Center, several directorates of the Office of the Chief of Naval Operations, and the Navy secretariat.

The work is organized into four clusters:

F. Personnel Recruiting aims at understanding the dynamics of the Navy's and Marine Corps' personnel accession processes and the economic, social and attitudinal factors affecting the decision to enlist.

G. Personnel Attrition research investigates the determinants of premature turnover and includes the experimental evaluation of selective counter-attrition policies and practices.

H. Manpower Supply focuses on methods for improving military manpower projections and on factors in the labor market that affect the supply of people for naval service.

I. Manpower Management seeks to identify methods and procedures that contribute to more effective personnel management practices and policies.

### **F. PERSONNEL RECRUITING**

Recruiting young men and women for naval service is a massive and expensive undertaking. This year the Navy has a goal of bringing in about 94,000 people with an overall recruiting budget of over \$150 million. More than 5000 people are directly involved in recruiting activities, and the advertising portion of the budget is over \$17 million. Because recruiting on this scale is a phenomenon going back only to the end of the draft, there are many issues that need investigation, and this portion of the program addresses some of them. An active steering group including the Commander, Navy Recruiting Command, and the Deputy Assistant Secretary of the Navy (Manpower), plays an oversight role in this area.

**EFFECT OF LOCAL ECONOMIC CONDITIONS ON NAVY ENLISTMENTS  
NR 170-870**

Information Spectrum, Inc./Rhode

Allocation of Navy recruiting resources should be based on accurate knowledge of local economic variables and how they interact with each other and with enlistments. This research will provide the basis for improved allocation of recruiting resources along geographic lines. Data are collected from the Enlisted Master File and other U.S. Government data bases (e.g., Labor Dept., Commerce Dept.). Cross-section and time-series analyses are conducted on the role of local economic variables in the enlistment process. When fully developed the model and software package will be provided to the Navy Recruiting Command. Funding: ONR

**OPTIMAL COMBINATION OF ADVERTISING AND RECRUITER EFFORTS NR 170-871**

Duke University/Morey

This effort has the thrust of being better able to predict and hence optimize the combined effects of advertising and recruiter efforts for the Navy's Recruiting Command. By being better able to simultaneously allocate and trade off both types of expenditures—against themselves, geographically, and over time—the Command can better meet its quality and quantity enlistment goals. The effort has developed and validated enlistment prediction functions which take into account differences in region, time of year, and type of recruit. It has also developed, programmed, exercised, and documented a budget allocation optimization program which uses as inputs the above prediction functions. The program can be used in budget preparation and execution and to help address policy issues. In addition to a technical report, a user's manual is available. A follow-on phase of the work involves further validation; i.e., the model is being tested for its ability to predict personnel accessions for FY 1978 from recruiting resource information for that year. Funding: ONR

Report:

Morey, R. C., & McCann, J. M. Budget allocation and enlistment prediction models for the Navy's Recruiting Command: The proper balance between recruiter and advertising efforts (Tech. Rep. 40-1). Duke University, May 1979

**ENLISTMENT IN THE NAVY AS A CASE OF OCCUPATIONAL CHOICE NR 170-872**

Mathtech, Inc./Wise & Nussbaum

Navy and Marine Corps recruitment programs require substantial data on the characteristics of different target groups and the factors that influence their occupational choices. This research will provide needed information on the occupational choice process. Using extant data and a human capital framework approach, the contractor is developing a model of occupational choice which takes into account individual characteristics (e.g., personality and motivation), economic conditions and indicators (e.g., *anticipated lifetime earnings*), and the characteristics of different Navy jobs. When completed, the model will identify population subgroups with the greatest potential for increased enlistment and the job characteristics that appeal most to these subgroups in their order of importance. Funding: ONR

**EFFECTS OF RECRUITING PERSONNEL AND ADVERTISING ON ACCESSIONS  
NR 170-874**

University of Pennsylvania/Carroll

The Navy needs improved measures of the impact and effectiveness of recruitment programs on enlistments. This research utilizes various Navy and Defense Department data bases to identify the variables involved and to evaluate the magnitude of the relationships. A set of test markets (Areas of Dominant Influence) are selected for field implementation of a two-factorial experimental design. Advertising and/or recruiter force levels are changed in the test markets for a one year period. Data from the test period is analyzed with historical data on enlistments for the all volunteer era. Numbers of enlistment contracts and/or market shares constitute the primary dependant variables for this analysis. Enlistment contracts are analyzed in various categories or "quality" profiles—high school graduate, non high school graduate, for example. Independent variables are advertising expenditure levels and recruiter force levels as well as demographic and economic data. Regression and correlation analysis are used to obtain response functions and elasticities. Funding: OASD(MRA&L)

## G. PERSONNEL ATTRITION

A major concern of Navy and Marine Corps manpower managers has been the rise in the proportion of first term enlistees who do not finish their obligated service. Such attrition rates are about 40%, and they have costly secondary effects: recruiting goals are increased, training loads go up, and, most importantly, fleet readiness is degraded. A subset of the attrition problem is desertions—the number of which is unacceptably high, i.e., nearly 14,000 incidents in FY 78. (Most deserters are separated, which has a significant effect on the overall strength of the enlisted force.) The two contracts described below concern a longitudinal study of attrition in the Marines and the development of techniques to enable recruits to cope with military life.

### LONGITUDINAL RESEARCH ON PERSONNEL ATTRITION NR 170-819

University of South Carolina/Mobley & Meglino

This research is designed to contribute to the understanding and prediction of first-term attrition and to experimentally evaluate selective counter-attrition policies and practices. A longitudinal design is being used to track, over the first enlistment, cohorts of male and female marines who entered Parris Island or San Diego in 1976, 1977 and 1978. Measures include demographics, expectations, intentions, and perceptions of alternative roles. Early results indicated expectations play a significant role in early attrition. In close cooperation with the Marine Corps an experimental realistic job preview, the Parris Island Recruit Assimilation Training Exercise (PIRATE), has been implemented and currently is being evaluated. Changes in expectations, coping behavior, and role attraction are evaluated in relation to performance and attrition. Funding: ONR

#### Reports

Ashworth, D. N., and Mobley, W. H. Relationships among organizational entry performance goals, subsequent goals, and performance in a military setting (Tech. Rep. 6). University of South Carolina, July 1978. (AD A059 031)

Catheart, J. S., Goddard, R. D., & Youngblood, S. A. Perceived job design constructs: Reliability and validity (Tech. Rep. 7). University of South Carolina, October 1978. (AD A062 865)

Griffeth, R. W., Meglino, B. M., Youngblood, S. A., & Mobley, W. H. Advanced training and initial duty station values,

expectations and intentions of Marine Corps enlisted personnel (Tech. Rep. 8). University of South Carolina, April 1979.

See also ARCHIVAL PUBLICATIONS: Mobley, Hand, Baker, & Meglino, 1979; Mobley, Griffeth, Hand, & Meglino, in press.

### EXPERIMENTAL COGNITIVE AND BEHAVIORAL SKILL TRAINING PROGRAMS TO REDUCE PERSONNEL ATTRITION NR 170-862

University of Washington/Sarason

This research is designed to develop experimental training programs for military recruits, in an attempt to reduce personnel attrition. The investigator is using interview and observational techniques to determine the nature of problems arising in recruit training that are associated with personnel attrition. These data will be used to determine precisely which cognitive and behavioral skills need the most emphasis in the experimental training programs. Prototype training programs similar to those that have been successful in preparing people for stressful civilian occupations will be developed and evaluated under controlled conditions. They will focus on the trainee's ability to make decisions under stress, to work with other individuals and groups, to concentrate on tasks at hand despite distracting, stressful conditions, and to deal with on-the-job frustrations adaptively. This program is derived from 6.1 research by the same investigator (NR 170-804). Funding: ONR

#### Reports:

See ARCHIVAL PUBLICATIONS: Sarason, Johnson & Siegel, 1978; Sarason & Johnson, 1979.

## H. MANPOWER SUPPLY

The potential supply of volunteers for manning the Navy is being threatened by two factors: a) the number of 17-21 year olds is dropping because of declining birthrates in the 1960's; b) there is increasing

## MANPOWER R&D PROGRAMS

competition for high quality youth from non-military federal programs, from industry, and from the other Services. Research was undertaken in 1976 to provide detailed information regarding manpower projections and the dynamics of the labor market as it related to military manpower availability. Initial emphasis was placed upon the examination of the possibility that existing manpower projection models could be extended or adapted to support the Navy's manpower planning functions. The combined efforts of the Urban Institute (NR 347-034) and the Wharton Econometric Forecasting Associates (NR 347-035) served as the centerpiece of that effort. This work has been brought to a conclusion during the current fiscal year. The results are somewhat ambiguous. It appears that the Urban and the Wharton models could be merged (in some sense) and that they could be adapted to serve Navy planners. However, attempts to date to tie this into the Navy have not been completely successful. Another contract (NR 049-418) in this cluster was completed during the year. It was a "shot in the dark" to examine the proposition that an untapped source of potential recruits is the offspring of military families. It turns out that the data required to deal with that proposition are not as readily available as originally expected, so the results are not as clear-cut as one might hope.

A recent workshop (NR 170-032) reviewed the manpower supply problems and research opportunities with senior DoD and Navy policy-makers and leading manpower researchers. The consensus of the group indicated more research in the area of manpower supply was needed. Consequently, research was recently initiated at the Pacific Academy for Advanced Studies on labor market characteristics affecting the recruiting process, which is described below under NR 047-210.

### **RECRUITMENT SUCCESS AND CIVILIAN LABOR MARKETS NR 047-210**

The Pacific Academy for Advanced  
Studies/Welch

This is a new effort that seeks to understand the local labor market characteristics that contribute to recruiting success (or failure). There are to be three parts: first, researchers are to compare characteristics of applicants for military service and those of actual recruits to characteristics of the populations from which they come. Comparisons of characteristics include age, education, race, and mental test scores. The objective is to determine whether recruit and civilian population characteristics differ through time and across local markets (large metropolitan areas and residual state rings). Trends since mid-1973 will be examined to determine the extent to which the supply of volunteers was diminished by previous inductions under the draft. The second phase will analyze civilian labor markets from 1967 to the present in terms of effects of local business cycles and longer trends. This part of the research seeks to understand the dependence between the local and national economies in generating opportunities for young men; it will also look at the ways local markets have dealt with a rising volume of new entrants from the baby boom of the 1950's. Labor market attributes in this phase of the research will include

wage rates, industrial mix, long- and short-run trends in employment, and institutional issues such as unionism, minimum wage legislation, and so forth. The third part of this work will be a synthesis of earlier findings to show how civilian labor markets affect recruiting and the types of men who volunteer. It is not the purpose of this research to forecast the supply of volunteers to the Navy; it is expected, however, that a better understanding of economic factors influencing local labor markets will be useful in developing forecasts and in forming manpower policies that integrate the needs of the Navy with the realities of the market. Funding: ONR

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The following work units in this cluster were completed during the past year.

### **THE ECONOMIC AND LABOR MARKET ENVIRONMENT OF MILITARY MANPOWER NR 347-034**

Urban Institute/Toikka

This research dealt with national economic policies and their impacts on the labor force; more particularly it sought to relate changes in the economy to military enlistments. The work was

undertaken in conjunction with that of another contractor, the Wharton Econometric Forecasting Associates (see below), and had as one of its objectives to translate general econometric forecasting models into measures more directly relevant to naval enlistment and reenlistment behavior. The first year saw the development of new simulation techniques and a synthesis of information from three previously disparate research areas: military recruitment, disaggregated labor market dynamics, and macroeconomic stability. The last, in the form of a Wharton model, was merged successfully with Urban's labor market model; this represented a technical accomplishment in that both structures were, initially, non-matching in several respects, e.g., time periods. The contractor was also concerned with recruit quality because it was well known that amount of education and ability test scores are negatively related to attrition; Urban sought to determine the available supply of volunteers at various mental ability and educational attainment levels. Results supported the hypothesis that recruit quality is positively correlated with the supply of applicants and negatively related to Navy accession demands. Simulations of the characteristics of Navy recruits projected over 15 years showed a persistent pattern of shortfalls. Policy options, both to increase supply and to reduce demand for non-prior-service recruits, were proposed and included higher compensation, acceptance of more woman, and less-labor-intensive manning patterns. Funding: ONR

## Report:

Greenston, P. M. & Toikka, R. S. The determinants of Navy recruit quality: Theory and evidence 1970-1977 (Tech Rep 1168) The Urban Institute, October 1978. (AD A061 054)

#### ECONOMIC AND MANPOWER FORECASTING NR 347-035

Wharton Econometric Forecasting Associates,  
Inc./Klein

This work was initiated in order to fill a need for sophisticated manpower supply forecasting techniques. The contractor had designed and was rou-

tinely providing short and long range socioeconomic projections for the U.S.; models generate details and make forecasts on employment, hours of work, hourly wages, annual incomes, etc., for such elements of the economic sector as agriculture, the construction and manufacturing industries, public utilities, wholesale and retail trades, and government. As a result of work under this contract WEFA has modeling capability for projecting short and long term trends in labor force, participation rates, employment, and unemployment by 14 age-sex groups. With this base WEFA research objectives are to: a) develop modeling capabilities to show how Navy occupational choices are related to national labor market conditions and to anticipated rates in competing job markets, and b) design more detailed models to demonstrate the relationship of age, race, education, and skill characteristics of the general labor force (as a product of socioeconomic conditions) to Navy manpower concerns. The general interest was to demonstrate the relationship between various socioeconomic variables and labor force behavior, to provide the Navy with modeling capabilities for forecasting trends, and to develop the tie between Navy manpower interests and occupational trends in the U.S. economy. More particularly, the Wharton effort aimed to map Navy recruiting districts into national geographic areas where economic status is known and is monitored by government census programs. The final report is forthcoming. Funding: ONR

#### INTERGENERATIONAL OCCUPATIONAL INHERITANCE NR 049-418

Bureau of Social Science Research, Inc./  
Biderman

This contract dealt with the tendency of children to "follow in the footsteps of their fathers," a tendency which has been statistically verified with respect to choice of occupation. The purpose of this exploratory effort was to examine the implications of that tendency for naval manpower planning. The question is, "To what extent will military careerists replace themselves?" BSSR's preliminary approach consisted of: a) conceptualizing the issues; b) identifying and assessing data bases that could be used in estimating the nature and extent of occupational inheritance in the Navy; c)

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evaluating the dimensions of succession phenomena and their significance for the Navy; and d) suggesting new avenues for research and routine data collection. This research was exploratory in nature, but some tentative conclusions for Navy manning policy can be drawn. For example, the pool of juniors, i.e., Navy offspring, will remain a significant source of recruits for the rest of the century. It is likely that juniors will have

significantly higher enlistment rates. There are ethnic differences, too, in that minority members tend to have higher reproduction rates and higher occupational succession rates. Funding: ONR

Report:

Biderman, A. D., & Haley, B. *An exploratory study of military intergenerational succession* (Tech. Rep. 1). Bureau of Social Science Research, Inc., June 1979

### I. MANPOWER MANAGEMENT

High manpower expenditures (over half the naval budget), tight manpower inventories, and pressing manpower commitments create many formidable manpower management problems. Research in this area examines certain possibilities for streamlining personnel operations, for estimating the value of current personnel resources, for identifying factors associated with the retention of skilled apprentices and journeymen, for estimating the future military adjustment of recruits, and for devising better methods of obtaining needed information from active duty personnel.

#### THE EFFECTS OF COMPENSATION ON VOLUNTARY ATTRITION OF ENLISTED PERSONNEL NR 047-182

Institute for Research Studies/Ghazalah

This research focuses on the relationship between pay in certain civilian occupations and the rate of attrition out of comparable Navy jobs. The analysis is considering naval personnel in three career groups: a) first termers, b) those who have completed their first term, and c) those who have completed additional terms of service. Data for these groups, categorized by rating or occupational specialty, have been converted to hourly rates for comparison with Bureau of the Census wage rates. A preliminary test of the research model, using nine major Navy occupational categories, has been completed. The study is now directed towards application of the model utilizing disaggregated data covering 42 individual ratings and 3 combined ratings for the period 1973 through the first quarter of 1979. This work is expected to provide badly needed data important to the retention of skilled apprentices and journeymen. Funding: ONR

#### IDENTIFICATION AND DEVELOPMENT OF UNOBTUSIVE MEASURES NR 047-184

Florida State University/Sechrest

Navy manpower and personnel managers have a continuing need for specific information about how

current or proposed policy changes are viewed by the people they affect. This research, begun late in FY 78, is working toward the development of new ways to assess attitudes. An underlying basis for the investigator's approach is his earlier work on unobtrusive and nonreactive measures. The current work will identify a variety of such measures to complement and/or substitute for more conventional attitude assessment methods. Initial developmental work has focused on the Recruit Training Command in Orlando. A variety of unobtrusive measures are routinely collected along with attitude surveys for all recruit companies. It will be possible to relate unobtrusive measures aggregated at the company level to attitude measures at the same level of aggregation, and the data will permit analysis of psychometric properties of the measures. Work is also proceeding on a generative taxonomy that should improve ability to devise new measures for specific purposes. In the meantime a monograph on unobtrusive measures has been published. Funding: ONR

Report:

See ARCHIVAL PUBLICATIONS: Smith, 1979

#### MANPOWER RESEARCH AND ADVISORY SERVICES NR 170-032

Smithsonian Institution/Sinaiko

There are two parts to this contract. The first concentrates on applied research over a range of



current naval manpower and personnel matters, with the objective of bringing together research findings that are relevant to naval manpower policy. Results of work sponsored by ONR and other agencies (Army, Air Force, and a number of non-defense agencies and organizations) are integrated in summary documents. Substantive issues have included first-term enlisted attrition, R&D manpower planning, and new manning sources. A workshop was conducted on the prediction of the supply of naval personnel; there was also a seminar on current and future issues in military manpower research. There is an active involvement with a British, Australian, Canadian, and U.S. consortium on military manpower trends, including the exchange of research findings and the conduct of collaborative work; personnel retention and future occupational structures are the focal points of current interests of that group. Under the same contract there is a second effort that serves to support the ONR basic research program. This is done by means of symposia, working groups, short term research, and expert consulting and advisory services. Among the topical areas covered by the last during the past year have been: personnel appraisal and compensation procedures, human memory, display technology, leader/group interaction, and criterion referenced testing. Funding: ONR

Report:

Cooper, W.W., Sinaiko, H.W., & Glassman, N.D. Management of Navy research and development manpower (Tech. Memo 1). Smithsonian Institution, January 1979.

The following work units in this cluster were completed during the past year.

#### **JOB EFFECTIVENESS OF ENLISTED PERSONNEL OF DIFFERING MENTAL ABILITIES NR 156-047**

Human Resources Research Organization/Vineberg

This work provides information about the job effectiveness of enlisted personnel of different mental-ability levels. In the initial phase, two instruments were developed for evaluating ...divi-

dual performance in several Navy ratings. One, a worker-oriented form, is based on a factor-analytic, structured job-analysis questionnaire known as the Position Analysis Questionnaire (PAQ), which was originally developed under ONR support (NR 150-372). The other form is a job-oriented instrument derived from the Navy Occupational Task Analysis Program (NOTAP), which provides an analysis of jobs based on their technological characteristics. Field trials were conducted to refine the instruments and compare them to standard Navy performance-rating forms. Within the limitations of a comparison of experimental and operational data, these task-specific instruments provide less error and better discrimination in evaluating job proficiency than standard Navy performance-rating forms. In a second phase, the forms were used to evaluate the job performance of men of varying mental ability and pay grade in nine technical Navy ratings. No clear evidence was obtained that persons in lower mental categories are less effective either in the rated quality of their performance or in the number and characteristics of duties they perform. In grades E3 and E4, supervisors perceive the most effective performers to be persons in either the highest or lowest mental categories, whereas persons from the middle of the range of mental ability tend to receive the lowest performance ratings. In grade E5, supervisors perceive the most effective performers to be persons in the lowest mental categories. The overall pattern is interpreted in terms of (1) the relative importance of technical (skill and knowledge) factors and nontechnical (e.g., motivation) factors in a job performance and their influence on ratings of performance, and (2) selective processes which favor the acquisition and retention in the Service of effective performers in the lower mental categories. As in the first phase, task level worker-oriented and job-oriented rating items showed more favorable properties for assessing performance than the Performance Evaluation Report used operationally in the Navy. These items, however, are still subject to bias effects. Leniency and halo increase with pay grade. Funding: ONR. CNET

Report:

Vineberg, R., & Joyner, J. N. Performance of men in different mental categories: 2. Assessment of performance in selected Navy jobs (Tech. Rep. 78-11) Human Resources Research Organization, September 1978 (AD A061 095)

**FUTURE PERFORMANCE TREND INDICATORS: A CURRENT VALUE APPROACH TO HUMAN RESOURCES ACCOUNTING**  
**NR 156-051**

University of Michigan/Bowers

The Navy and Marine Corps, like other large organizations, need to be able to assess the impact that current management practices are likely to have on future effectiveness of the organization. The process of compiling and assessing this information is known as Human Resource Accounting. This research was concerned with building a methodology for human resource accounting based on a "present value" approach—that is, an approach involving the estimation of the future productive capability of present human resources. There were two phases of this work. The first investigated the nature of the relationship between the human organization and organizational effectiveness (the latter being measured by absenteeism and total variable expense). Phase 2, value attribution, consisted of three steps: a) changes in performance were predicted; b) the dollar values of those changes were estimated; and c) future values were capitalized and discounted. Phase 2 was applied using available business and industrial data. Applying linear multiple regression techniques, the *Survey of Organizations*, an instrument developed earlier, under a previous ONR contract, was used to predict effectiveness, i.e., absenteeism and total variable expense. In general it was shown that "today's management practices affect tomorrow's organizational effectiveness." More specifically it was shown that time lags of nine to 18 months characterized the "policy-change-to-observable-effect" phenomenon. The research also showed, using value attribution procedures, that even small changes in the human side of the organization can yield significant improvements in future performance. Finally, it was established that human resources accounting procedures could be extended to Navy applications; significant relationships were found between Human Resources Management Survey measures and Navy performance, e.g., operational readiness and reenlistment rates. Michigan investigators conclude that human resources accounting would be applicable in developing a "future performance trend indicator" system. Funding: ONR

Reports

Bowers, D. G., Franklin, J. L., & Pecorella, P. A. Future indicators of Navy Performance: An extension of current value concepts to Navy data (Tech. Rep. 6). University of Michigan, July 1978. (AD A057 509)

Bowers, D. G., & Davenport, A. S. Future performance trend indicators: A current value approach to human resources accounting. Utilization problems tied to methodological issues (Tech. Rep. 7). University of Michigan, August 1978. (AD A058 831)

Pecorella, P. A., Bowers, D. G., Davenport, A. S., & LaPointe, J. B. Forecasting performance in organizations: an application of current value human resources accounting (Final Report). University of Michigan, August 1978. (AD A060 102)

Davenport, A. S., & Bowers, D. G. Organizational diagnosis: Issues and methods (Final Tech. Rep.) University of Michigan, February 1979. (AD A065 289)

**LIFE PATH AS A PREDICTOR OF PERFORMANCE IN THE NAVY**  
**NR 170-875**

Richard A. Gibboney Associates, Inc./Daniel

This research was undertaken as an extension of earlier, basic research which had led to the development of a technique for measuring "life path experiences." These experiences refer, in the main, to individuals' encounters with institutions: legal, educational, familial, etc. The current work was an investigation of the relationship between "life path" and the performance of naval recruits. One phase of the research explored racial implications of "life path"; i.e., it tried to explain differences between the performance in recruit training of black and white seamen. Another phase analyzed the "life path" instrument as a means of identifying naval personnel who would be candidates for remediation and special counseling. In the absence of such programs these recruits are likely to be candidates for early attrition from the Navy, or, at best to become disciplinary problems. There are policy implications in this work for retention in the career force, and the "life path" instrument is seen as an attractive diagnostic technique for implementing them. A final report is forthcoming. Funding: ONR

## ORGANIZATIONAL EFFECTIVENESS RESEARCH PROGRAMS [CLUSTERS J-N]

These programs aim at enhancing the performance of Naval crews, teams, and other groups by contributing to the development of principles governing human interactions, ranging from informal face-to-face encounters between individuals up to formal interactions between large organizations. Research in this area increases understanding of the ways interactions develop and the relationships between human interactions and organizational effectiveness. The individual research contracts that comprise the programs fall into the five clusters below.

J. Adaptation in Organizations. Research on the factors that determine how individuals adapt to work in organizations and the ways in which organizations can be changed to enhance work performance and satisfaction.

K. Intergroup Relations. Aims at improving our understanding of how individuals with diverse ethnic and cultural backgrounds can be merged into effective teams, crews and units.

L. Personnel Turnover and Retention. Research and development on the determinants and impact of personnel turnover.

M. Leadership and Management. Theoretical and empirical research with the ultimate aim of improving programs of leader and manager development.

N. National Security Crisis Management. A program of the Defense Advanced Research Projects Agency designed to increase the effectiveness of crisis decision making.

### J. ADAPTATION IN ORGANIZATIONS

The research presented in this cluster is directed at providing a better understanding of how to increase and maintain productivity, efficiency, and morale in organizations. Organizations (those settings in which there is a division of labor and in which authority occurs at several levels) provide the context for the overwhelming majority of workers. Seeking a better understanding of the relationship between the individual and the organization could be justified solely on the basis of the amount of time that individuals spend interacting with organizations. ONR provides support for basic research on organizations varying in complexity from small work groups to entire ships or shore units. Reflecting such diversity, this cluster contains the largest number of work units. Ongoing work emphasizes both the adaptation of the individual to the demands of the organization (e.g., adjustments necessitated by initiation into the organization, or working for extended periods in a socially restricted environment) and adjustments in the organization itself which accommodate the needs of individuals (e.g., research into the nature of the "healthy" organization, the long-term outcomes of innovative programs, and effective communication patterns in organizations). Research initiated in FY 1979 includes a major effort aimed at developing more powerful methodological techniques for research on organizations. A second major thrust with long-term implications involves the development of a blueprint for future research on crews, groups, teams, and units (CGTU). This effort is being coordinated with, and funded by, all three branches of the Division. It addresses team-related research in the areas of human engineering, personnel and training, and organizational effectiveness. This program, as it develops more fully, will be coordinated with CNET, NPRDC, TAEG, NADC, OPNAV, NTEC, and the Marine Corps.

**DATA ACCURACY IN SOCIAL NETWORK ANALYSIS NR 170-793**

West Virginia University/Bernard &amp; Killworth

One promising method for improving criteria of organizational effectiveness involves analyses of human communication networks (i.e., who talks to whom). Bernard and Killworth are developing a quantitative theory of group dynamics. In pursuit of such a theory they have developed and refined a model of dynamic social networks through the analysis of data from "closed" social systems (e.g., prisons, research vessels, naval training units). Effort is also being directed at determining the error bounds of data-collection methods customarily used in sociometric analyses. A principal accomplishment of the research has been the development of "CATIJ", a method for describing the structure of communication networks in complex organizations with up to 150 members. A computer program was also developed to perform the computations required in CATIJ. Data for this method consist of responses to questions about whom subjects like, trust, talk to, work with, etc. The error bounds of this instrument were assessed by comparing reported instances of communication with objective records in five groups (ham radio operators, deaf teletype communicators, workers in two different work groups, and members of a college fraternity). The results of that assessment indicated that there were no known error bounds, which suggests that theories of communication based on such data may be suspect. Current work involves experiments to map the behavioral and cognitive social structures of very large human groups. Funding: ONR

## Reports:

Bernard, H. R. & Killworth, P. D. A note on some very rich network data (Tech. Rep. No. KB-118-78) West Virginia University, October 1978

See also ARCHIVAL PUBLICATIONS Bernard, 1978, Bernard & Killworth, 1978 (a), (b), (c).

**INCREASED WORK PRODUCTIVITY AND QUALITY THROUGH SELF REWARDING NR 170-828**

Georgia Institute of Technology/Blood

Controversy exists as to the relative effects of intrinsic and extrinsic rewards on job performance.

This research explores factors that determine the incidence and the effectiveness of certain intrinsic rewards (that is, those that inhere in the job content or the worker's perception of the job) on the quality and quantity of work performed. Empirical research in laboratory and field settings is underway to determine how the work situation and supervision operate to increase, or decrease, self rewarding behavior and what organizational interventions could be used to increase the incidence of self rewards. A model of the way self rewarding interacts with other variables to determine job performance has been developed and was presented at a NATO conference on organizational problems. Research has confirmed the conceptual model of self rewarding. Currently the results of a field intervention designed to improve the quantity and quality of performance by increasing self rewarding are being prepared for publication. Funding: ONR

## Report:

Blood, M.R. & Thoene, J.F. Self rewarding as an influence on industrial performance (Tech. Rep. No. 3), Georgia Institute of Technology, July 1978

**IMPROVING THE CREDIBILITY AND IMPACT OF MANAGERIAL COMMUNICATION BEHAVIOR NR 170-830**

Syracuse University/Klauss

This research investigates the relationships among managers' interpersonal communication behavior, satisfaction with colleagues, job satisfaction and performance. A two-stage communication model has been elaborated in which six dimensions (careful presentation of ideas, open, two-way communication, frankness, careful listening, brevity, informality) serving as independent variables were seen to impact four intervening variables (colleague role clarity, manager trustworthiness, informativeness, and dynamism). These intervening variables, in turn, were seen to influence the following dependent variables: colleague satisfaction with manager, job satisfaction and work-group effectiveness. One test of the model involved a survey of 348 managers in a large organization. Respondents were asked to describe their own bosses in terms of the dimensions mentioned above. In addition, respondents provided data concerning their own sense of role clarity and information on their job

satisfaction and performance. Multiple regression analysis, partial correlation analysis, and path analysis were used to test hypotheses that stemmed from the model. The model explained 77% of the variance for "satisfaction with supervision" and considerably less variance for "job satisfaction" (30%) and "work group effectiveness" (28%). Additional research has examined the reliability and validity of the scales employed in the research and has also considered the impact of organization size and technology on communication behavior. Funding: ONR, NAVMAT

Report

Klauss, R., Bass, B.M. & DeMarco, J.J. The impact of organization size and technology on managerial communication style, its credibility and consequences (Tech. Rep. No. 5) Syracuse University, February 1978.

# **PRINCIPLES AND GUIDELINES FOR DESIGNING ORGANIZATIONAL DEVELOPMENT PROGRAMS NR 170-840**

Texas Christian University/Sells

Both theoretical and applied objectives are addressed in this research. The theoretical objectives are related to general principles of organizational behavior and interactional psychology. The applied objectives are focused on methods of organizational development. This research is based on an interactionist model which assumes that the impact of organizational development programs depends not only on program content but also on the characteristics of the individuals involved and the situations in which they work. Psychological instruments were developed to tap each of these areas. Research on civilian samples (computer programmers, firefighters, and production line personnel) resulted in an analytic model that includes organizational-environmental factors as perceived, attitudes and performance variables, as well as interactions among these, as a basis for understanding and predicting organizational behavior. Research is now being extended to Navy personnel. The products of the research will include a set of guidelines for use by Navy human resource program managers. Funding: ONR, NMPC (BUPERS)

Reports

Stackleth, J.D., Jones, L.R. & Sells, S.B. An examination of the use of data from existing Navy records and data bases as

indicators of human resource management needs and operational readiness (Tech. Rep. No. 78-15). Texas Christian University, October 1978.

James, L.R. & Jones, A.P. Perceived job characteristics and job satisfaction: An examination of reciprocal causation (Tech. Rep. No. 79-5). Texas Christian University, April 1979.

See also ARCHIVAL PUBLICATIONS: James, Hater, Gent. & Brunt, 1978; James, Hornick, & Demaree, 1978; James & Singh, 1978; Jones & James, 1979.

# **FACILITIES MAINTENANCE IN NAVY SHIPS NR 170-844**

Old Dominion University/Morgan

Under modification to the basic contract, and with funding provided by the Naval Ship Research and Development Center (NSRDC), this ongoing effort has recently been modified from one focused on "The Influence of Institutional Incentives on Middle Management in Hierarchical Organizations" to one concerned with facilities maintenance in Navy ships. The purpose of the current research is to provide NSRDC with data necessary to evaluate the acceptability, utility, and cost-effectiveness of three experimental facilities maintenance innovations. Specifically, special equipment, a management system, and special training materials are being evaluated in various combinations using two classes of Navy ships. The research is aimed at determining whether the innovations reduce the number of man-hours required to clean and preserve the ship and/or improve the cleanliness and appearance of the ship. Useable results of this investigation will be implemented on a navywide basis. Funding: NSRDC

# **LONGITUDINAL, MULTIVARIATE INVESTIGATION OF ORGANIZATIONAL EFFECTIVENESS NR 170-877**

University of Illinois/Terborg

Accurate prediction of the effectiveness of a military organization under various scenarios requires the analyst to take into account the characteristics of the individuals in the organization, its internal environment (e.g., leadership, organization size, advancement rates), and the external environment (e.g., population density, unemployment rate). Most organizational effectiveness research focuses on only one or two of these variable sets.

Terborg's recently initiated longitudinal study will include consideration of all three sets. Several indicators of organizational effectiveness such as profitability, expert judgement, organizational stability, and morale will be used. The data base for this study has been developed over the past few years and includes high quality information from a Fortune 500 company. In addition, Terborg is studying the process of employee organizational attachment as indexed by employee attitudes, advancement, and turnover in a university setting. Funding: ONR

**EXPERIMENTAL ANALYSIS OF SMALL-GROUP PERFORMANCE EFFECTIVENESS  
NR 170-855**

The Johns Hopkins University School of Medicine/  
Brady & Emurian

Experiments are conducted with small groups of volunteer participants within the context of a self-contained laboratory programmed to provide both individual and group opportunities for work and recreation over extended periods of continuous residence under biologically and behaviorally supportive environmental conditions. Initial studies with groups of two and three persons were conducted with the objective of evaluating and optimizing conditions which enhance habitability and productivity during intervals extending up to several weeks of continuous residence in the programmed environment. The baseline individual and social behaviors observed under such confined-microsociety conditions were further analyzed in relation to effects of cooperative and non-cooperative social contingency arrangements upon individual and group performance effectiveness. Ongoing studies continue to address the analysis of motivational processes in this context with a focus upon variations in the programmed appetitive and aversive consequences of required work tasks. In addition, studies have been extended to analyze the effects of behavioral program variables on individual and small-group performance effectiveness with particular reference to the relationship between on-duty performance and off-duty behavior. Funding: ONR

**Reports:**

Emurian, H. H., Emurian, C. S., Schmier, F. R., & Brady, J. V., Methodological and operational aspects of programmed

environment research (Tech. Rep. No. 3). The Johns Hopkins University, April 1979.

Emurian, H. H. & Brady, J. V., Extended analysis of small group performance and the effects of contingency management in a programmed environment (Tech. Rep. No. 4). The Johns Hopkins University, April 1979.

**PSYCHOLOGICAL FACTORS IN COMPUTER-CONTROLLED MESSAGE SYSTEMS**

**NR 170-866**

Stanford University/Zimbardo

Optimal team performance requires that each member's input to the group task represents the highest potential contribution by the member. This research aims at determining the influence of psychological factors on the attainment of such a goal with regard to the level of verbal participation in a group problem-solving task. A longer-term objective is the development of techniques to offset the influence of factors found to inhibit full participation. The approach involves the development and utilization of a computer-controlled message-handling system which permits systematic variation and control of the factors under study. Research completed to date indicates that participation rates vary as a function of member assertiveness and that participation can be altered by establishing an equal-time rule for participation. Future research will address ways in which apprehension affects problem solving and methods for reducing communication anxiety. Funding: ONR

**Report:**

Zimbardo, P. G., Assessment of the utility of an automated message system to influence participation rates among problem-solving teams varying in communication apprehension (Tech. Rep. No. Z-S-01). Stanford University, January 1979.

**CAREER-CHANGE STRESSES**

**NR 170-868**

University of Michigan/French

This research develops a general theory of adjustment that focuses on the goodness of fit between the person and the environment. It will consider how coping, defenses and social support are involved in re-establishing good person-environment fit following the midlife career

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changes experienced by enlisted men joining the Fleet Reserve after serving for 20 years. Another topic of interest is the retention of sailors who decide to remain in the Navy beyond 20 years. The study is primarily longitudinal but will include cross-sectional comparisons as well. The first phase of the research includes intensive clinical interviews, pilot-testing new questionnaire measures of coping and defense, and refining occupational indices used in earlier projects. The initial phase of the study allows for the clinical validation of measures and the development of instruments that will be used in the later mail-questionnaire phase of the study. Funding: ONR

### **THE SOCIAL LEARNING OF WORK-ROLE BEHAVIORS AND ATTITUDES NR 170-876** Purdue University/Weiss

We don't know enough about how persons acquire work-role behaviors and attitudes even though a number of relevant theories have been developed and tested aimed at predicting and understanding such behaviors and attitudes. Social learning theory seeks to explain psychological functioning in terms of reciprocal interactions among behavioral, cognitive and environmental influences. Many contemporary psychologists view social learning theory as an advancement beyond Hull's classic S-R theory and find it useful for generating testable hypotheses in the field as well as in the laboratory. However, few organizational psychologists have capitalized on its findings and implications. Weiss is using Bandura's social learning theory to explore the acquisition and development of work-role behaviors and attitudes. In general, he is investigating the nature and extent of observational role-learning processes in organizations. Specifically, he seeks to learn about the relationship between observational learning processes and work-attitude development, the conditions which influence work-attitude development, and the possible impacts of social learning processes on absenteeism and attrition. His methods include laboratory, simulation, and field studies. Funding: ONR

#### Reports:

Weiss H.M. & Shaw, J.B., The influence of models' attitudes on observers' judgments about task characteristics (Tech. Rep. No. 1). Purdue University, March 1979.

Weiss, H.M. & Knight, K.A., Self esteem, information search and problem efficiency (Tech. Rep. No. 2) Purdue University, May 1979.

See also ARCHIVAL PUBLICATIONS Weiss & Shaw, in press.

### **CREATING LONG-TERM ORGANIZATIONAL CHANGE NR 170-884** Carnegie-Mellon/Goodman

Many operational programs have been initiated to improve the quality of working life and to increase productivity and worker satisfaction. Much research has accompanied these efforts and has increased our understanding of the short-term consequences of interventions in the workplace. What is not understood however, are factors which relate to sustained change and strategies for managing organizational improvement programs over extended time periods. This research involves a selective literature review on factors which affect whether or not a change is successfully sustained over time. Data will also be collected from several organizations which have undertaken major organizational development projects in the 1970s. Analyses will focus on the factors which sustain change, early warning signs of decline, and strategies for organizational renewal. Funding: ONR

### **MILITARY FAMILY RESEARCH NR 170-888** United States International University/Hunter

Until recently the military family has been neglected as a subject for scientific research. Current interest within the services and the scientific community indicates the need for a compilation of available research. The objective of this recently initiated effort funded by the Air Force and monitored by ONR is to compile an annotated bibliography of research on the military family. The approach includes a search of both published and unpublished material. The final report will include a description of each reference as well as a notation as to how each document can be obtained. Funding: AFOSR

**INCREASING PRODUCTIVITY THROUGH  
GOAL SETTING NR 170-890**

University of Maryland/Locke

This research examines the relationship between productivity and various aspects of goal setting. Available research indicates that productivity increases when specific, difficult goals are set in a participatory environment. Techniques that result in workers setting, accepting and achieving difficult goals are addressed in this research. After compiling and evaluating the existing research on goal setting, Locke will conduct a series of laboratory experiments addressing specific gaps and inconsistencies in the literature. Variables which have been found to affect goal setting (e.g., need achievement, management style, monetary incentive, supervisory power, feedback) will be manipulated in order to provide a more coherent picture of their relationships to goal setting. Funding: ONR

**DEVELOPING INNOVATIVE METHODS FOR  
STUDYING ORGANIZATIONS NR 170-895**

American Psychological Association/Hackman

In every field of scientific endeavor researchers often pause to question the methods they are using in their attempts to understand the phenomenon under study. It is this questioning that often sows the seeds for innovative change and allows for new perspectives on difficult problems. This research is directed at generating and disseminating innovative methodological materials in organizational psychology. By bringing together some of the most respected researchers in the field and assigning them specific areas of methodology, a more systematic knowledge base for understanding organizational phenomena will be developed. The examination of methodological issues will occur in a series of conferences at which methodological alternatives will be generated and examined. Innovations based on these alternatives will then be tested and disseminated. Funding: NIE, ONR

**RESEARCH PLAN FOR TEAMS IN TECHNOLOGICAL SETTINGS NR 170-898**

Rand/Thorndyke & Weiner

In response to a need for a long-range plan for research on teams, this effort will provide a blue-

print for basic research in this area. Included in the plan will be an outline of the relevant research that needs to be undertaken and the requirements for integrating research across the areas of personnel and training, organizational effectiveness, and human engineering. This research is being supported by all three branches of the Psychological Sciences Division and addresses the specific concerns of each. The plan for research will serve to guide larger efforts in the future aimed at a better basic understanding of team training, team composition, and the interface of team and technology. Funding: ONR

**THE EFFECTS OF SOCIAL STRUCTURE,  
TECHNOLOGY AND JOB DESIGN ON JOB  
SATISFACTION IN THE NAVY NR 170-841**

Battelle Human Affairs Research Centers/Lawler

This research studies the relationships between the technological characteristics of Navy jobs and their psychological characteristics (autonomy, identity, variety, etc.). The information produced adds to the precision with which job design or redesign endeavors can be predicted to impact on organizational effectiveness indicators. Multivariate analytic techniques are used to determine the nature of relationships among several sets of variables: (a) three dimensions of technology involving the nature of the raw material or input, the equipment used to process the input, and the feedback received from persons or machines; (b) four core psychological task characteristics (the extent to which workers feel personal responsibility for their work, the extent to which they can see that they have produced something of consequence, the number of skills involved in the work, and the feedback received from supervisors and co-workers); (c) a measure of the amount of interaction with other individuals in the work situation; and (d) measures of job satisfaction. Current work examines the interaction of these variables for Navy chief petty officers who have jobs which require multiple skills. Funding: ONR

The following work units in this cluster were completed during the past year.



**IMPROVING GROUP PERFORMANCE EFFECTIVENESS NR 170-744**

Yale University/Hackman

Hackman has produced a model that specifies some conditions under which individuals will become internally motivated to perform effectively on their jobs. The model focuses on the interaction among three classes of variables: (a) the psychological states of employees that must be present for internally motivated work behavior to develop; (b) the characteristics of jobs that can create these psychological states; and (c) the attributes of individuals that determine how positively a person will respond to a complex and challenging job. A related model, which identifies factors that are important in designing and managing interacting work teams, has also been developed. Funding: ONR

Report:

Hackman, R.J. Work Design in the organizational context (Tech. Rep. No. 17). Yale University, December 1978.

**A STUDY OF DISTANCE, BAYESIAN, AND DECISION-TREE METHODS OF ORGANIZATIONAL DIAGNOSIS NR 170-839**

University of Michigan/Bowers

Increasingly, organizations such as the U.S. Navy are adopting organizational development techniques to enhance their effectiveness. Following an assessment of the state of an organization's "health," remedial actions are undertaken to correct identified deficiencies. This research was

aimed at improving the precision with which organizational practitioners can diagnose specific organizational problems and recommend appropriate actions. Specifically, given comparable quantitative measurements of units (individual, work group, or department) of an organization and a typology of "health" states, the accurate assignment of units to types within the typology is important. To this end, a comparative analysis of four analytic methods was undertaken to determine which would most effectively classify various units which are themselves in different organizational effectiveness states. These included multiple discriminant, Bayes classification, decision-tree and distance-function methods. The final report delineates the advantages and disadvantages of each method of analysis and indicates its effectiveness with data very similar to that handled by the Navy's Human Resource Management System. Particular findings of note include the conclusions that: (1) the decision-tree method of analysis is easy to use in the field because of low computational requirements, but its use results in misdiagnosis more frequently than do the other methods of analysis; (2) the distance-function technique provides the most accurate diagnosis that can be obtained on-site using a hand calculator; and (3) sampling procedures involving surveys of fewer than two-thirds of the members of the organization often lead to misdiagnosis, indicating that the standard sampling procedures used in social science may be inappropriate for organizational development. Funding: ONR

Report:

Bowers, D., Organizational diagnosis: Issues and methods (Final Rep.). University of Michigan, February 1979.

**K. INTERGROUP RELATIONS**

ONR-sponsored research on intergroup relations began in the early 1970's with a focus on developing knowledge needed to increase harmonious intergroup relations and reduce intergroup hostilities evident in the Navy. These efforts were followed by research aimed at assessing the existence and nature of racism and parallel laboratory and field studies of the dynamics of interactions among persons from different racial groups. Work units completed during this year include an examination of discrimination against women along with efforts to explore influences on their career motivation and success (NR 170-796 and NR 170-858).

Since the technology for documenting various kinds of discrimination is well developed, additional ONR-supported research along this line is not anticipated. Instead, the current program focuses on identifying

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and describing the situation or context (individual, small group and organizational) that results in the desired quality of intergroup relations. The primary objectives of the current program are to produce models and criteria for effective intergroup behavior in a broad range of settings. A new thrust in this area is an effort to build a knowledge base with a near-term application aimed at increasing the recruitment and retention of Hispanic personnel. Longer-term efforts along this line are intended to explore the variables (economic, social, cultural, vocational, psychological and the like) pertinent to recruiting, educating and training, managing, and retaining sailors and marines from all eligible categories. The key word here is diversity (e.g., with regard to age, sex, culture), and future research will be oriented toward providing the information required for maintaining an effective Navy and Marine Corps, comprised of diverse and heterogeneous individuals.

In this area the major users include the following: Deputy Assistant Secretary of the Navy (Equal Opportunity); Deputy Chief of Naval Operations (Human Resources Management); Navy Military Personnel Command (Equal Opportunity); Navy Personnel Research and Development Center (Attitude and Motivation Program and Acquisition and Initial Service Program); counterparts of the above in the other services; and selected programs in other Federal agencies such as the National Institute of Education's Educational Equity Program and the National Institute of Mental Health's Center for Minority Group Mental Health Programs.

During January 1979, the second annual contractors' meeting was held for the cluster of projects described below. Such meetings typically include the researchers, ONR scientists, and representatives from the above user communities. This meeting focused on the criterion problem in intergroup relations and included a critical review of ongoing work units as well as some guidelines for future research in this area.

### **EFFECTIVE RESPONSES TO PROBLEMATIC INTERETHNIC SITUATIONS NR 170-851** Institute of Behavioral Sciences/Dinges

The increasing number of racially mixed work groups may lead to an increase in the frequency of problematic interethnic situations and the need for greater interethnic competence. While much is known about interethnic attitudes, rather less is known about effective behavior in interethnic situations. A great deal of race and human relations education/training is being conducted and there is a need for behavioral anchors to serve as education/training goals and as evaluation criteria. Initial efforts focused on the identification, description, and classification of problematic interethnic situations with regard to content, frequency, and difficulty. Preliminary results of the analysis of problematic interethnic situations were then used to develop videotaped stimulus situations in which responses were obtained to situations which were varied systematically for ethnicity, situational content, and situational difficulty. Data are being collected using ethnically different judges to assess both subjective and objective aspects of effective and ineffective responses. Later stages of the research are to involve the development of

behaviorally anchored scales reflecting personal and situational variables involved in effective and ineffective responses. The final stage entails the construction of a dynamic model of interethnic competence. It is anticipated that such a model will explain and predict effective interethnic interactions and guide future research on the personal and situational variables involved in interethnic competence. Funding: ONR

### **BEHAVIORAL CRITERIA FOR HUMAN/ETHNIC RELATIONS NR 170-854**

The Urban Institute for Human Services, Inc./  
Hilliard

The lack of theoretically grounded behavioral criteria for human/race relations programs has impeded the advancement of a variety of educational, training and action efforts to improve relations among diverse groups of people. This work unit explores behavioral, not attitudinal, criteria for effective interpersonal and interethnic behavior. Its primary objective is to examine the feasibility and utility of selected behavioral criteria for one standardized human/race relations educational technique. Its secondary objective is to

refine those criteria for generic use. In pursuit of the above objectives a literature review has been conducted which focuses on the development and use of behavioral criteria. Interviews and site visits to institutions working in the area of human or ethnic relations have been conducted. A theoretical model to guide criteria selection and development has been formulated and continues to be refined. The model includes new insights into the role of historical information in intergroup relations. A preliminary set of criteria is currently being used in an experimental trial with pre-, post-, and follow-up tests. Funding: ONR

Report:

Hilliard, A. G., Jenkins, Y.L., & Scott, M.C., Behavioral criteria in research and the study of racism: Performing the jackal function (Part 1) (Tech. Rep. No. 1). The Urban Institute for Human Services, Inc., January 1979.

**METHOD AND THEORY DEVELOPMENT FOR STUDYING INTERGROUP RELATIONS IN ORGANIZATIONS NR 170-891**

Yale University/Alderfer

The purpose of this effort is to develop a new methodology for studying intergroup relations in organizations. This includes the development of an accompanying theoretical formulation describing group and intergroup dynamics that occur in organizations. The investigator has collected (over the past decade) a large volume of quantitative data on the attitudes and beliefs of persons of different races and ages within the same organizations. This work unit will primarily entail analysis of that data base in order to fine-tune a new methodology and shed some empirical light on a new theoretical framework. The two primary foci are race relations among managers of different races and age group dynamics among managers. The effects of, and relationships among, group membership, group perceptions, identity group, organizational group, and individual attitudes and beliefs are being analyzed. Funding: ONR

Report:

See ARCHIVAL PUBLICATIONS: Alderfer & Guzzo, 1979.

**THE ORGANIZATION OF SOCIAL INFORMATION NR 170-882**

Ohio State University/Ostrom

The manner in which people organize social information is related to how much they trust or cooperate with others, as well as how much they discriminate against or reject others. This is particularly true in heterogeneous environments such as the Navy and Marine Corps. This project is designed to explore how people organize information about others, especially when several bits of information are obtained about several different people. Its general objective is to expand theory and knowledge about the role of informational factors in the person-by-person organization of social information. A specific objective is to identify the determinants of person perception. These objectives are being sought through a series of laboratory studies. The first set of studies examined the effects of familiarity on the processing of information about other persons. This set has been completed and showed that familiarity has a strong influence on how people cognitively organize social information. Information acquired about familiar persons is organized in terms of the persons themselves; information about unfamiliar others tends to be organized in other ways (e.g., by temporal order of acquisition or by descriptor category). Future studies are aimed at specific components of familiarity such as perceptual discriminability, social discriminability, and frequency of association. Funding: ONR

Report:

Ostrom, T.M., Lingle, J.H., Pryor, J.B., & Geva, N., Cognitive organization of person impressions (Tech. Rep. No. 1). The Ohio State University, May 1979.

See also ARCHIVAL PUBLICATIONS: Lingle & Ostrom, 1979; Lingle, Geva, Ostrom, Leippe, & Baumgardner, 1979.

The following work units in this cluster were completed during the past year.

**FACTORS INFLUENCING SUPERIOR-SUBORDINATE BEHAVIOR IN EMERGENCY SITUATIONS NR 170-784**

University of Delaware/Gaertner

Complaints of Navy minority personnel center around alleged inequitable treatment in assignment, promotion, and punishment. Although

much has been done to discourage personal and institutional discrimination, there are still many opportunities for personal prejudice to operate. This seems particularly evident when one is in a position (superior) where discrete choices to help or not help someone, such as a subordinate, can be made. Employing both field and laboratory studies, Gaertner's research explored the area of personal prejudice by examining mechanisms involved in differential interpretation of "emergency situations" as dependent upon the perceived race of the "victim." Studies were conducted using students and persons selected from the general population to explore factors that would reduce the effects of the victim's race on helping during a simulated emergency. Findings to date suggest that minimizing the opportunity to diffuse responsibility for not helping facilitates helping behavior among Blacks and Whites. Recent studies also indicated that Whites are less inclined to assist Blacks of higher status or in superior roles. Funding: ONR

Report

Gaertner, D., The subtlety of white racism. A final report (Tech. Rep.) University of Delaware, October 1978.

**MORE EFFECTIVE USE OF WOMEN IN THE ALL-VOLUNTEER NAVY NR 170-796**  
University City Science Center/Kirkland

The number of women in the Navy has increased significantly, as have career opportunities for women in previously all-male specialties. This research focused on the status relationships between men and women, with particular emphasis on aspects of male and female roles that influence leadership behavior. A second interest was in factors which differentially influence male and female career motivation. Special observation techniques, including new analytic methods, were developed. Experiments were conducted to assess the effects of gender-related variables on the performance of laboratory tasks. A large survey-data base was developed to address the above issues, containing data obtained from subjects with ages and occupations that will facilitate generalization of results to the Navy, and including male and female subjects in ROTC programs as well as men and women in private industry. This contract has involved support both from the Organizational Effectiveness

**Research Programs and from the Manpower R&D Program. Funding: ONR**

Reports:

Good, J. & Kirkland, F.R., Attitudes toward selected job characteristics in a working population with cross-sample analyses for a college sample (Tech. Rep. No. 5). University City Science Center, June 1979.

Good, J., Kirkland, F.R., & Grissom, G.R., Working relationships between men and women: Effects of sex and hierarchical position on perception of self and others in a work setting (Tech. Rep. No. 6). University City Science Center, June 1979.

**SEX-SPECIFIC STEREOTYPING, REWARD SYSTEMS AND RESPONSE PATTERNS IN WORK GROUPS NR 170-858**

Validated Instruction Associates/Hinsdale

This contractor conducted applied research and a series of workshops for the Bureau of Naval Personnel designed to enable Navy women to recognize and overcome the internal and external barriers to career advancement that they encounter on a day-to-day basis, in themselves and in their work groups. Among these barriers are certain psychological and behavioral characteristics of women, sex-role stereotyping on the part of work-group members, and the widespread absence of role models. The applied research and training activities have been closely coordinated with the basic research supported by ONR. Both branches of the project were guided by a psychosocial model of defeat, developed by Hinsdale, which describes in behavioral terms how sex-role stereotyping within the work group interacts with motivational constructs (e.g., achievement anxiety, low self-confidence, fear of success) to produce a "cycle of defeat." The result of this cycle is the reinforcement of precisely those fears and attitudes which prevent most women from deviating from traditional feminine behavioral norms. The model also delineates paths to success or ways of breaking the cycle of defeat. The purpose of the basic research work unit was to validate, or invalidate, the model as it applies to both males and females, including intensive analyses of paths to failure and success for Navy women. In the basic research, support was found for the general human dynamics described by the model. Men and women differed in behavioral responses to punitive situations and

in their emotional responses to punitive situations in which traditionally masculine behaviors were displayed. An androgynous standard of behavior was found to be more adaptive in work groups than either a masculine or a feminine standard of behavior. In the applied research Navy women were found to display a rather narrow spectrum of behaviors to potentially awkward situations. A pilot program which taught these women to expand the range of those responses in ways acceptable to a hierarchical organization proved successful. Funding: ONR

Reports:

Hinsdale, K. & Johnson, J. D. Masculinity, femininity, and androgyny: What really works at work? (Tech. Rep. No. 2). Validated Instruction Assoc., Inc., October, 1978.

Hinsdale, K. & Johnson, J.D. Stereotypes of working women: Fact or fiction? (Tech. Rep. No. 3). Validated Instruction Assoc., Inc., November, 1978.

Hinsdale, K. & Johnson, J.D. Women in work groups: Misperceptions and missed expectations (Tech. Rep. No. 4). Validated Instruction Assoc., Inc., November, 1978.

Hinsdale, K., Patterns of approval in work groups: Treating the sexes equally (Tech. Rep. No. 5). Validated Instruction Assoc., Inc. December, 1978.

Hinsdale, K., & Johnson, J.D., Working women and the cycle of defeat: Sex-specific responses and their emotional and behavioral consequences (Tech. Rep. No. 6). Validated Instruction Assoc., Inc., January, 1979.

Hinsdale, K. & Cook, J. W. Sex-specific stereotyping, reward systems, and response patterns in work groups (Final Rep.) Validated Instruction Assoc., Inc., March, 1979

See also ARCHIVAL PUBLICATIONS: Hinsdale & Cook, 1978.

# **EXPLORING THE NATURE AND MISSION RELATEDNESS OF DISCRIMINATION** **NR 170-860**

Behavior Design Incorporated/O'Connor

This project was designed to fill a current gap in the research base for Navy equal-opportunity, affirmative-action and race-relations activities. It was aimed at education and training programs as well as management. This work unit was unique in the field of intergroup relations because it examined the relationship between discrimination and mission readiness by identifying specific actions taken by persons and organizations which might be discriminatory. These actions were analyzed with respect to their effects on organizational and individual performance. The measurement system for this work unit had been pre-tested and specifically oriented toward Navy personnel. The key features of the system are observations and in-depth, candid and confidential interviews. The data were treated to correlate the form and incidence of race- or sex-biased behaviors and systems with factors determining mission readiness. Findings indicated significant race- and sex-based obstacles to combat readiness. Funding: BuPers, ONR

Report:

O'Connor, R.D., The nature and mission-relatedness of race and sex discrimination in the Navy (Final Rep.) Behavior Design, Inc., December 1978

## **L. PERSONNEL TURNOVER AND RETENTION**

These efforts are designed to produce new theories and models of the determinants of personnel turnover and to conduct empirical laboratory and field studies. After the initial work units on determinants, costs, and effects have been completed, the objective will be to produce interactive computerized management systems which will provide the opportunity to check out the effects of various personnel and manpower policy changes before they are actually implemented.

## **THE EFFECTS OF ORGANIZATIONAL STRUCTURE AND DEMOGRAPHIC CHARACTERISTICS ON WORK**

**NR 170-802**

University of Illinois/Hulin

Hulin treats worker attitudes and behavior as a joint function of individual, demographic,

economic, and organizational variables. The dependent variables of particular interest include absenteeism, turnover, and job satisfaction at the individual level, and unit effectiveness at the group level. Instruments have been developed and a major longitudinal study has been undertaken of approximately 50 units of the Illinois National Guard. Hulin found that, among other things, a

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high level of technology is not detrimental to worker satisfaction, and (in addition to autonomy and a sense of responsibility for an entire task) is actually predictive of job satisfaction. In this final year of the contract, Hulin is organizing his research findings of the past five years into a comprehensive model of worker attitudes and behavior. Funding: ONR

### Reports:

Hom, P. W. & Hulin, C. L. A comparative examination of four different approaches to the prediction of organizational withdrawal (Tech. Rep. No. 78-5). University of Illinois, December 1978.

Miller, H.E., Katerberg, R. J., Hulin, C. L. An evaluation of the Mobley, Horner, Hollingsworth model of employee turnover: Validation data and suggested modifications (Tech. Rep. No. 79-11). University of Illinois, January 1979.

### EFFECTS OF LIFE STRESS AND COPING SKILLS ON PERFORMANCE AND ORGANIZATIONAL EFFECTIVENESS

NR 170-804

University of Washington/Sarason

Environmental stressors, life stress, organizational stress, and coping skills all influence how people handle problematic situations. This research has produced new measures of personal and organizational stress. A variety of techniques are being developed to strengthen adaptive cognitive responses to stress. Experiments have been conducted with both civilian and military groups exposed to high levels of job stress. Results indicate that: (1) a piling up of negative life changes has a significant impact on personal effectiveness; (2) there is no comparable effect for positive life changes; and (3) training in specific coping skills fosters improved performance. Research has also been conducted on the role of variables that moderate the effects of life stress. One group of these variables are personality characteristics (such as sensation-seeking and locus of control), while another group consists of environmental conditions (such as the degree to which the environment is supportive). Funding: ONR

### Reports:

Johnson, J. H. & Sarason, I. G. Moderator variables in life stress research (Tech. Rep. No. SCS-LS-007 (No. 11)). University of Washington, February 1979.

Sarason, I. G., Life stress, self-preoccupation, and social supports (Tech. Rep. No. SCS-LC-008 (No. 12)). University of Washington, April 1979.

See Also ARCHIVAL PUBLICATIONS: Smith & Sarason, 1978; Johnson & Sarason, 1978; Sarason, Johnson, & Siegel, 1978; Sarason & Johnson, 1979.

### COMMITMENT, CAREERS, AND RETENTION IN ORGANIZATIONS NR 170-812

University of Oregon/Steers

This research is designed to examine the complex interrelationships which exist among employee career patterns, commitment and attachment to organizations, and subsequent employee turnover and absenteeism. The major thrust of the project has been the development of empirically based theoretical models of employee attachment processes. A measure of employee commitment to organizations has been developed and validated, and has been used to examine the antecedents and outcomes of organizational commitment in a variety of organizational settings and among diverse types of employees. This research has demonstrated that employee commitment to organizations is influenced by employee characteristics, job characteristics, and work experiences. Moreover, the measure of organizational commitment has been found in several studies to be related to employee turnover and absenteeism. Recent work has also involved an extensive review of empirical research on employee absenteeism in organizations, from which a process model of absenteeism has been developed identifying the major influences on this behavior. Research is being carried out on the development of employee attitudes and on the psychological processes by which individuals and their peers accommodate to the decision to participate or withdraw. A model has been developed outlining both the factors leading up to the turnover decision and the means by which people accommodate to the decision once it is made. Funding: ONR

### Reports:

Steers, R. M., Goal-setting, supervisory behavior, and employee turnover: A field experiment (Tech. Rep. No. 17). University of Oregon, November 1978.

See also ARCHIVAL PUBLICATIONS: Koch & Steers, 1978; Steers & Rhodes, 1978; Steers & Spencer, 1978; Morris, Steers, & Koch, 1979; Mowday, 1979; Mowday & Steers, 1979; Mowday, Steers, & Porter, 1979; Steers & Porters, 1979.

**DAILY PATTERNS OF LIFE STRESSORS  
AND THEIR RELATION TO HEALTH  
NR 170-861**

Research Foundation for Mental Hygiene/Neale

The prevailing belief is that exposure to life events often precedes and causes somatic illness, and that some individuals are particularly vulnerable to stress because of their history of exposure to certain life events. However, the relevant literature contains few, if any, studies that have controlled for a number of possible artifacts that need to be considered. This research is designed to provide an improved methodology for assessing the relationships among one's past history, current exposure to stress, incidence of illness, and current vulnerability to stress. The investigators have constructed and pilot-tested new and improved instruments for assessing the daily incidence of exposure to stressful life events and the subject's psychological perceptions of these events. Each event that occurs is rated with respect to a number of dimensions (i.e., the amount of change, control, desirability, and meaningfulness). Daily symptoms are recorded and rated for severity. In addition, each subject fills out a daily adjective checklist which yields scores indicating the subject's mood at a given point in time. The exposure to stressful life events instruments along with the above checklist are now being responded to by a large sample of the general population. The mood scores and the exposure measures will be related in a prospective research design to the frequency and severity of illnesses. Funding: ONR

**WORK CONTEXT INTERACTIONS, WORK  
CLIMATE AND TURNOVER NR 170-894**

Michigan State University/Schneider

This effort is aimed at providing empirical evidence for a theoretical model describing how work context interactions (with the work itself, superiors and peers) and work climate (organizational and psychological, structural and perceptual) combine to produce turnover. A multi-faceted methodology including observations, surveys, quasi-experiments, laboratory experiments, field studies, base-line establishment, and longitudinal analyses is being used. Instruments include aptitude tests,

job analysis and diagnosis inventories, measures of work climate, and indices of participation, as well as the standard types of measures used in experiments and quasi-experiments. The research is being guided by a theoretical framework developed during the past ten years by the investigator. The framework describes how an individual's interactions with his or her job in a particular job context lead to various degrees of participation, from high participation to withdrawal. Funding: ONR

**AN INVESTIGATION OF THE IMPACT OF  
INDIVIDUAL AND ORGANIZATIONAL  
CONTEXTS UPON THE CONSEQUENCES OF  
JOB SCOPE NR 170-892**

University of Wisconsin/Cummings & Dunham

All of the services have recently begun to pay a significant amount of attention to such ideas as job design, job redesign, job enrichment and job scope. Of those terms, job redesign, job design, and job scope are the most fruitful subjects for research in terms of their potential for increased organizational effectiveness and decreased attrition. For example, prediction of attendance and performance outcomes is enhanced by including considerations of individual and organizational contexts. This particular research is expected to provide some of the knowledge needed to identify specific locations for making job changes, to accurately predict the effect of job changes, to determine what types of job changes would be most effective, and to estimate cost/benefit ratios for changes in job scope. Funding: ONR

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The following work units in this cluster were completed during the past year.

**SEA AND SHORE ROTATION: THE FAMILY  
AND SEPARATION NR 170-835**

Anthropological Inquiry Services/Snyder

This research utilized the skills and techniques of cultural anthropology in an attempt to determine

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*the effects of periodic separation, induced by alternate sea- and shore-duty assignments of the husband, upon the Navy family. It is worth noting that the principal investigator on this work unit is the wife of a submariner. The project was closely coordinated with the Naval Regional Medical Clinic at Pearl Harbor, where much of the data were obtained. The work was also reviewed by, and conducted with the enthusiastic cooperation of the Commander of the Pacific Fleet Submarine Force, Admiral C. H. Griffiths. He later became the Deputy Chief of Naval Operations for Submarine Warfare and continued to monitor and make substantive contributions to the research. Returning to the work itself, a broad range of methods was used in this effort including participant observation, interviews, and analyses of available medical records. Outcomes of the project indicated that the separation/reunion cycle profoundly affected the woman's performance of traditional spouse duties, caused her to become ill more during the husband's absence, and led her to be consistently anxious and depressed. It also seemed evident that the woman's systemic reaction to the sea-shore rotation affected the husband's performance of Navy duties and his occupational satisfaction. The theme of successful versus unsuccessful coping behavior is evident throughout the technical reports generated in this effort. Funding: ONR*

### Reports:

Snyder, A.I. The effects of husband's at-sea time upon the role playing behavior of the submariner's wife (Tech. Rep. No. 3). Anthropological Inquiry Services, 1978.

Snyder, A.I. Periodic marital separation and physical illness (Tech. Rep. No. 4). Anthropological Inquiry Services, 1978.

Snyder, A.I. Sea and shore rotation: The family and separation (Phase II Final Report - FR78). Anthropological Inquiry Services, 1978.

See also ARCHIVAL PUBLICATIONS: Snyder, 1978, (a), (b).

## NAVAL OFFICER CAREERS AND THE QUALITY OF LIFE: IMPLICATIONS FOR RETENTION AND PRODUCTIVITY

NR 170-836

Naval Postgraduate School/Derr

This research examines career values and quality-of-life orientations as they affect naval officers' careers. Derr has developed measures which can be used to match career values and life orientations at various career stages. Analyses of career switching patterns in naval officers reveals an inverse relationship between the extent of second career planning and the potential for productivity within the Navy. This research has implications for officer selection and career enrichment/development and should lead to better retention rates, job satisfaction, and performance. Funding: ONR

### Report:

Derr, C.B. Career switching and career strategies among U.S. Naval officers (Tech. Rep. No. 1). Naval Postgraduate School, May 1979.

See also ARCHIVAL PUBLICATIONS: Derr & Schein, 1978; Derr, in press.

## M. LEADERSHIP AND MANAGEMENT

In a changing Navy, an understanding of how best to provide leadership—the organization, direction, and motivation of subordinates— remains critical. Research to provide an empirical scientific basis for the selection, training, and assessment of leaders for a variety of positions is described in the following cluster. The approaches are as diverse as the problems and include theory development (NR 170-824), investigation of training techniques for leaders (NR 170-825), and on-site data gathering (NR 170-805). The selection and training of people to fill the variety of leadership functions requires a clear understanding of the potential demands of the leadership positions as well as the learning of required behavior techniques. A new work unit (NR 170-893) examines the variety of training techniques for leadership in both civilian and military settings. Such research provides data which will help match effective training programs to leadership needs.



We have provided consultative input to the Leadership Management Education and Training (LMET) program, and we believe that the implementation of the LMET program is indicative of the view that leadership training can pay potentially high dividends. ONR contractors engaging in leadership research met at Duke University in April of 1979 to discuss progress and exchange views on current and future leadership research. The range of topics discussed indicated that current conceptions of leadership range from the simple facilitation of day-to-day operations in an organization to providing subordinates with guidance during conflict, decisiveness in crises, and inspiration under fire. Research in the leadership area in the future will continue to address the questions on a broad front, eventually incorporating information gained from other clusters with an increasing emphasis on understanding effective leadership in organizations with increasingly diverse membership.

### **LEADERSHIP EFFECTIVENESS: CULTURAL AND COGNITIVE CORRELATES**

**NR 170-807**

Systems and Evaluations/Ramirez & Castaneda

This unit seeks to identify characteristics related to leadership effectiveness in mixed groups. The focus has been on three personality characteristics: biculturalism (the ability to function comfortably and effectively in Mexican-American and in mainstream-American cultures), bicognition (the ability to function in "field-sensitive" and "field-independent" cognitive styles), and interethnic skills (the ability to mediate and facilitate interactions among people of different ethnic groups). Life histories have been developed for assessing these characteristics in college students of Mexican descent. Together with other psychological measures, these life histories have been used to assess developmental antecedents and cultural and linguistic variables associated with the three personality variables. A comparison is now being made between bicultural subjects and non-bicultural subjects. Data collection includes a life history, the California Psychological Inventory, Rokeach Values Scale, the Rotter, a language dominance/bilingualism measure, and an assessment of leadership potential and flexibility. Data are being collected in California and Texas. Small group laboratory studies are currently being conducted to determine if bicultural subjects who are bicognitive and report possessing interethnic skills and experience will be more effective leaders of ethnically mixed groups than subjects who do not have these characteristics. Funding: ONR

Report

Ramirez, III, M., Cox, B.G., & Castaneda, J. Dimensions of biculturalism in Mexican-American college students. Tech Rep No. 21. Systems and Evaluations, September 1978

See also ARCHIVAL PUBLICATIONS: Ramirez & Cox, in press.

### **RESEARCH ON THE METHODOLOGY OF LEADERSHIP TRAINING NR 170-893**

Human Resources Research Organization/Olmstead

Although leadership training occurs in a variety of civilian and military settings, there remain numerous unresolved questions about the efficacy of the various methods used in training leaders and the conditions under which each method will be most effective. Furthermore, there is no established method for comparing the effectiveness of the techniques vis-a-vis the specific goals of training. This research is devoted to an analysis of civilian and military leadership training programs. It will examine methods and issues involved in such training as well as research designed to improve leadership training technology. Training methods will be analyzed and evaluated with respect to their effectiveness in achieving predetermined goals. Guidelines will be developed for designing and implementing leadership training programs. Finally, a framework to provide guidance for selecting training approaches according to leadership requirements and relative effectiveness of the methods will be developed. Funding: ONR

### **ORGANIZATIONAL MAINTENANCE: BEHAVIORAL ANALYSIS AND INTERVENTION NR 170-881**

Georgia Institute of Technology/Komaki

There is an increasing need for research on ways to improve and sustain performance related to equipment maintenance. This work unit is organized to design, implement, and evaluate a program

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using the behavior-analysis technique to improve organizational maintenance in a Fleet Marine Force Unit. The long-term research objectives include an expansion of the knowledge base on reinforcement contingencies, feedback, and the effectiveness of various incentives. It is also anticipated that our understanding of how behavioral techniques influence attitudes will be enhanced. The technical approach, behavior analysis, includes six basic components: (a) specification of the desired performance; (b) repeated measurement of performance on specific tasks; (c) an analysis of the work environment to determine the factors hindering and facilitating performance; (d) an intervention based on the positive reinforcement part of reinforcement theory; (e) an evaluation to determine the effectiveness of the intervention in the work setting; and (f) analyses to pursue the longer-term research objectives. The specific target site and groups have been identified and an area of preventive maintenance has been selected for investigation. The measurement system has been constructed, field tested, and finalized and provides on-site observations using trained observers. Six separate measures of preventive maintenance are collected: time utilization, supervision, knowledge/training, identification accuracy, follow-through action, and the condition of the vehicles. Baseline observations have been collected over a period of four months. The positive reinforcement intervention has been introduced in one unit, with feedback about performance and time-off as reinforcers. Funding: ONR

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The following work units in this cluster were completed during the past year.

### INFORMATION PROCESSING MODELS OF PEER NOMINATIONS NR 170-805

Duke University/Lewin

*This research was aimed at the development of an information processing theory of the judgmental processes which individuals engage in while rating their peers. The military services have found peer ratings to be quite useful in certain aspects of personnel research and operations, but little detailed information has been available concerning the*

human judgmental processes involved in making such evaluations. The approach taken here was to utilize protocol-tracing methods (analysis of verbalized thought processes) and to construct decision-process models of how individuals rate their peers on several sociometric questions of leadership. Completed research indicates that peer ratings appear to be sensitive to population and situation differences as well as the unique attributions of the causes of peer behavior that are affected by these differences. Important implications of the results for questionnaire design, the leader assessment process, and future research on the attribution of leadership have been elucidated. Funding: ONR

#### Report:

Lewin, A.Y. & Layman, S.S. The effect of quantity and content of communications on the nominations of emergent leaders (Tech. Rep. No. 8). Duke University, November 1978.

### LEADERSHIP RESEARCH IN A RECRUIT TRAINING COMMAND SETTING

NR 170-823

Naval Training Equipment Center/Blaiwes

This effort involved partial support of a program carried out at the Naval Training Equipment Center aimed at exploiting the capabilities of a sophisticated computer-assisted learning system for upgrading social-interaction skills (leadership) of recruit company commanders. The program produced a variety of computer-assisted methods for teaching managerial and communication skills. These have been evaluated in three separate field experiments. The latest version of these training programs has been prepared for adoption by the Recruit Training Command, Orlando. Recent developments include computer-based programs for (a) evaluating and managing recruit company commanders and other aspects of the Recruit Training Command; and (b) assisting in the processes of evaluating video-taped interpersonal performance and providing feedback to the performers. Recruit Training Command, Orlando, is utilizing some of these programs on a routine basis under their own control. Funding: ONR

#### Reports

Blaiwes, A.S. & Weller, D.R. A computerized evaluation and training system (CETS) for recruit training commands. An

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overview. (Tech. Rep. NAVTRAEQUIPCEN IH 307). Naval Training Equipment Center, November 1978.

Blaiwes, A.S., Weller, D.R., & Romot, G. Development and implementation of a computerized evaluation and training system (CETS) at a recruit training command (Tech. Rep. NAVTRAEQUIPCEN IH 300). Naval Training Equipment Center, March 1978.

Weller, D.R. & Blaiwes, A.S. Computer-assisted judging and feedback of interpersonal skills (Tech. Rep. NAVTRAEQUIPCEN IH 308). Naval Training Equipment Center, December 1978.

### RELATIONAL QUALITIES OF LEADERSHIP STYLE NR 170-824

State University of New York at Buffalo/Hollander

This research aimed at clarifying leader/follower relationships and how they influence the effectiveness of leadership. It involved a literature review, a "critical incident" survey, the development of measures of leader/follower relations which defined leadership style, and experimental studies of social exchange dimensions. Consistent differences were found among ratings on these dimensions when situations of effective and ineffective leadership, or of appointed and elected leadership were compared. A later series of field studies utilized individuals in "middle-level" leadership roles who have the dual perspective of both leader and follower. While the findings from this series were numerous, at least two general conclusions should be noted. First, the transactional approach clearly demonstrated that an active sense of the follower role is likely to lead to greater involvement in groups and organizations. This was accompanied by a host of specific conclusions showing how leaders and followers accommodate to each others' expectations. Second, when dealing with mixed-sex groups the comparative effectiveness of male or female leaders depends heavily on such factors as the nature of the group task, the attitudes about appropriate sex-roles held by the leader and followers, and the kind of criterion measures used. Funding: ONR

#### Reports:

Hollander, E.P. & Yoder, J. Some issues in comparing women and men as leaders (Tech. Rep. No. 7). State University of New York at Buffalo, November 1978.

Neider, L.L., Carpenter, W.A. & Hollander, E.P. Assessing good and bad leadership using critical incidents and rating

scales in three organizational settings (Tech. Rep. No. 8). State University of New York at Buffalo, July 1979.

See also ARCHIVAL PUBLICATIONS: Hollander & Julian, 1978.

### LEADERSHIP IN CONTEXT: AN ORGANIZATIONAL SIMULATION NR 170-825

Center for Creative Leadership/McCall

This research aimed at the development of an organizational simulation which will permit systematic manipulation of leadership variables in a controlled environment resembling the richness and complexity of real world organizations. "Looking Glass, Inc.," the simulated organization, is a three-division manufacturing organization of moderate size. Twenty managers, ranging from President to Plant Manager, run the corporation for a day. The problems they face were drawn from intensive field interviews and plant visits and are intended to simulate typical events in a manager's day. The external environments of the three divisions vary from volatile (the Advanced Products Division) to stable (the Commercial Glass Division), permitting direct measurement of environmental influences on leadership processes. Looking Glass has been run ten times under controlled conditions. Norms will soon be available based on measures of activity patterns, power distributions, organizational climate, information processing, decision-making, and individual, group, and organizational effectiveness. Also available soon will be data relevant to the validity of Looking Glass, especially activity patterns of managers in the simulation versus in field settings. Looking Glass has been adapted for use by British managers (Looking Glass Limited) and is being used to generate cross-cultural norms. It has been run successfully with managers from government, education, banking, and manufacturing organizations. Funding: ONR

#### Reports:

McCall, M.W., Jr. & Lombardo, M.M. Looking Glass, Inc.: An organizational simulation (Operational Manual Vol. I). Greensboro, N.C.: Center for Creative Leadership, October 1978.

Lombardo, M.M. Looking Glass, Inc.: Advanced Products Division (Operational Manual Vol. II). Greensboro, N.C.: Center for Creative Leadership, 1978.

## ORGANIZATIONAL EFFECTIVENESS RESEARCH PROGRAMS

McCall, M.W., Jr. Looking Glass, Inc.: Commercial Glass Division (Operational Manual Vol. III). Greensboro, N.C.: Center for Creative Leadership, 1978.

DeVries, D.L. Looking Glass, Inc.: Industrial Glass Division (Operational Manual Vol. IV). Greensboro, N.C.: Center for Creative Leadership, 1978.

Lombardo, M.M., McCall, M.W., Jr. & DeVries, D.L. Looking Glass, Inc.: Outside information notebook (Operational

Manual Vol. V). Greensboro, N.C.: Center for Creative Leadership, 1978.

Lombardo, M.M. Looking at leadership: Some neglected issues (Tech. Rep. No. 6). Center for Creative Leadership, January 1978.

McCall, M.W., Jr. Leadership as a design problem (Tech. Rep. No. 5). Center for Creative Leadership, January 1978.

## N. NATIONAL SECURITY CRISIS MANAGEMENT

The following contracts represent that part of the Defense Advanced Research Projects Agency's program on national security crisis management that is monitored by ONR. The general goal of this program is to increase the effectiveness of decision making during international and intra-national crises. More specifically, the program is developing short- and long-term crisis forecasting techniques; models of the crisis management organizations of several nations; and interactive, computer-based aids containing military, political and economic indicators for monitoring international affairs and warning of crises, as well as executive aids for crisis management.

### DEVELOPMENT OF A CRISIS EARLY WARNING PROTOTYPE SYSTEM NR 170-821

International Public Policy Research Corp./Daniels

This research is one of the most applied efforts within the Crisis Management Program. It provides continuous integration of the results received from other research projects in the Program in order to develop an early warning system that reflects as realistically as possible, and that detects as early as possible, changes among the interactions of nation-states in the international arena. At its completion, the system is expected to be functioning in many DoD agencies as a sophisticated early warning system in support and enhancement of ongoing analytical efforts performed by U.S. Government analysts in the field of foreign affairs. Combining techniques from quantitative political science and international relations, computer science, and decision theory, this synergistic methodology addresses the identification of international event-interaction data from relevant political, economic and military indicators; the development and refinement of software for a computer-based system; and the testing of the system's ability to forecast international crises accurately. Funding: DARPA

Report

See ARCHIVAL PUBLICATIONS: Hopple, in press.

The following work units in this cluster were completed during the past year.

### CROSS-NATIONAL CRISIS INDICATORS NR 170-777

University of Maryland/Wilkenfeld

The Cross-National Crisis Indicators Project, a logical extension of the Interstate Behavior Analysis (IBA) Project conducted during the 1974-1977 time period, was designed to enhance national crisis warning capabilities by pursuing two general research goals. The first involved the development of interstate and intra-state indicators. Indicator systems were designed to monitor the interstate and internal arenas of states in order to generate information about potential crisis situations. Trend data for the period 1966-1977 were utilized to develop and test these indicators. The second general objective entailed the testing of integrated crisis models designed to illuminate the interrelationships among the indicators. These models have been incorporated into the real-time crisis warning system under development by the Defense Advanced Research Projects Agency. Funding: DARPA

Report:

Hopple, G. W., Final report of the cross-national crisis indicators project (Final Tech. Rep.). University of Maryland.

**CRISIS WARNING AND MANAGEMENT  
NR 170-798**

University of Maryland/Bobrow

The Crisis Warning and Management Project was comprised of long-term research aimed at the design and evaluation of techniques for monitoring and analyzing the crisis behavior of nations and the efficient organization of crisis action groups in the United States Department of Defense. The ultimate objective was the development of a set of methodologies which could serve as components of a crisis warning and management system. The utility of these various techniques was assessed through their application to the crisis behavior of particular nations. The initial cases selected were the People's Republic of China and the United States. A number of analyses were completed including differential news coverage of various Chinese public media, the People's Daily treatment of different international actors, and the mapping of Chinese perceptions of the conflict dynamics of the early period of the Vietnam war. Analytic and modeling techniques were developed which have successfully reduced forecasting error. Funding: DARPA

**CRISIS FORECASTING  
NR 170-838**

Carnegie-Mellon University/Duncan & Job

The Crisis Forecasting research project formed a key methodological element in the DARPA-sponsored crisis management program. It was designed to improve forecasting through the development and application of stochastic modeling techniques, specifically Markov renewal process models, to international relations research. To enhance the Markov renewal process, appropriate Bayesian statistical procedures were developed and applied. Simulation examples include the analysis of a set of data representing movements over time of events/interactions among three states. Further modeling efforts were considered from the point of view of application to real life crises, where Bayesian procedures in particular allow the expertise of foreign affairs analysts to be incorporated. Funding: DARPA

**EXECUTIVE AIDS FOR  
CRISIS MANAGEMENT NR 170-843**  
CACI, Inc.-Federal/Mahoney

This research was aimed at the development of executive aids for DoD crisis managers. These aids allow planners and decision-makers to make use of historical precedents to guide option selection and evaluation for current crises. The aids' data bases cover U. S. and Soviet crisis characteristics for the period 1946-1978 and the characteristics of Chinese crises for the period 1949-1978. Subsets of the U.S. and Soviet data bases, selected because of their relevance for current planning, have been coded for crisis actions, objectives, problems, and outcomes. Funding: DARPA

Report:

See ARCHIVAL PUBLICATIONS: Abolfathi, Hayes, & Hayes, 1979.

**THE USE OF SOVIET ARMED FORCES AS A  
POLITICAL INSTRUMENT SINCE THE  
SECOND WORLD WAR  
NR 170-856**

The Brookings Institution/Kaplan

This research effort determined how the Soviet Union used its armed forces as a political instrument—i.e., as a means of influencing the decisions of foreign governments—in a great number of occasions since the Second World War. The purpose of this research was to provide U.S. policy makers and crisis managers with a better understanding of the political-military adversary relationship that exists between the U.S. and the U.S.S.R. through an analysis of incidents of Soviet political-military behavior, an assessment of the effectiveness of such uses of military force and their significance to U.S. interests, and the identification of trends in Soviet political-military activity and its implications for U.S. foreign and defense policy. Funding: DARPA

Report:

See ARCHIVAL PUBLICATIONS: Blechman & Kaplan, 1978

**CRISIS MANAGEMENT DEVELOPMENT AND  
DEMONSTRATION FACILITY NR 170-857**  
Computer Corporation of America/Rothnie

The establishment of the Development and Demonstration Facility (DDF) constituted a major improvement in the DARPA Crisis Management Program (CMP), the aims of which included the development and testing of computer-based warning and monitoring systems, executive management aids, and experimental implementation and evaluation thereof. The DDF responds to development, demonstration and transfer needs. It enables multiple users to develop software, maintain data bases, conduct statistical analyses and demonstrate various products, thus eliminating duplicate research and equipment acquisition by other CMP contractors. The DDF allows the CMP to accelerate the development of user engineered computer-based products, as well as to pursue such development in cumulative and cost-effective ways. Moreover, the DDF averts the production of products which are incompatible with user hardware/software configurations and it allows potential users to "participate" in the development of crisis management products through coordinated demonstrations. Products of the DDF have been transferred to a test bed at the National Military Indications Center (NMIC) in the Defense Intelligence Agency (DIA) as well as to the Naval Postgraduate School. Funding: DARPA

**NATIONAL ESTIMATES NR 170-865**  
University of Michigan/Organski

The National Estimates Project was devoted to the study of the development of a nation-state's capability to preserve its influence in the international

arena by focusing on the demographic, social, political, and economic components of power. It was intended to balance the extensive research devoted to the military component. The major methodological approach consisted of applying fiscal theory and fiscal data extraction under the assumption that the ability of a government to collect revenue reflects to a great extent the social-economic conditions of that particular nation-state. Results from this research have been deposited in the ARPA Crisis Management Demonstration and Development Facility. Funding: DARPA

**TOWARDS A GENERAL FORECASTING  
MODEL FOR CRISIS MONITORING: A  
CHINESE TEST CASE NR 170-873**  
Michigan State University/Li

A General Forecasting Model for Crisis Monitoring addressed the need for further development of a variety of intra-national forecasting techniques that will be simple and easy to use by those in the operational communities who have little computer or statistical training. Specifically, this research was devoted to the development of a computer-based forecasting system, with feedback control, which generates predictions from a single series of observations or through leading indicators in real time. As a test model, Chinese elite and political-economic-military data are applied in order to determine crisis and policy indicators. The system design, interactive software, and forecasting methods of this effort are designed to fulfill DARPA Crisis Management Program (CMP) technical requirements and will be included in the CMP's Development and Demonstration Facility prior to application within U.S. Government agencies. Funding: DARPA

## **ENGINEERING PSYCHOLOGY PROGRAMS (CLUSTERS O-R)**

Our Engineering Psychology Programs are concerned with assuring effective performance by personnel working with the high technology equipment characteristic of modern Navy and Marine Corps systems. We seek better fundamental understanding of human perceptual, decision-making and psychomotor behavior, in order to develop general guidelines for the design of compatible interfaces between people and their machines. We are particularly interested in research that shows how personnel performance can be improved through simplified procedures and built-in performance aids. We are also interested in the development of equipment-design principles that will lead to reduced training requirements.

Our programs are organized into four clusters:

O. Man-Machine System Interfaces. This focuses on the human control of systems and vehicles. Current emphasis is on advanced computer-aided control and related display technologies.

P. Visual and Auditory Perception. This work aims at broadening the data base and advancing selected aspects of perceptual theory. We are phasing out threshold-level studies, and are significantly increasing attempts to understand more complex supra-threshold situations involving perception of multi-dimensional signals. This shift is motivated by new requirements stemming from increased use of computer-generated displays and the anticipated future introduction of three-dimensional imagery.

Q. Information Processing and Decision-Making. This research is seeking to understand how people assess situations and select actions under conditions of uncertainty and risk; it also includes investigation of computer programmer performance. There has been increased emphasis on the role of individual differences and the effect of task characteristics in decision performance, and on understanding how people generate new hypotheses and new action choices.

R. Decision Aid Development. These efforts are funded under 6.2 and 6.3 budget categories. They are based on results from previous fundamental (6.1) research, such as that described in Cluster Q. The current exploratory and applied efforts concern the development and evaluation of techniques and displays to aid decision making in command and control systems. During the past year, we have moved to broaden the spectrum of system types with which the program is concerned.

### **O. MAN-MACHINE SYSTEM INTERFACES**

This cluster is concerned with the perceptual, cognitive and motor capabilities of people who operate the controls of naval equipment. For several years our research has been studying the effects of computer-assisted supervisory control techniques, man-computer communication links in control systems and the impact of degraded visual and other informational feedback on the operation of controls. Concepts and models developed thus far have proven useful in development of underwater teleoperator systems at the Naval Ocean Systems Center. A portion of this research has been investigating performance of humans as team members in systems, with particular emphasis on understanding the requirements for information exchange. This aspect of the research will be expanded as part of a new multi-disciplinary program in

crew, group, team and unit (CGTU) performance to be undertaken by the Division. Another new thrust, is the attempt to understand and predict mental workload as a function of the characteristics of various types of tasks and man-machine interfaces. This work is closely coordinated with research on pilot workload being conducted at the Naval Air Test Center.

In the coming year, renewed efforts will be made to better understand the problems faced by maintainers of Naval equipment. Certain equipment design features place excessive skill and performance requirements on maintenance personnel; research will be undertaken to investigate this matter. If successful, we will develop concepts for simplifying future equipment and for selectively introducing built-in aids to improve maintainability.

#### **MAN-MACHINE COMMUNICATION IN COMPUTER AIDED TELEOPERATOR CONTROL NR 196-140**

Perceptronics, Inc./Crooks

Advances in computer-aided teleoperator control offer the potential for substantially improving the effectiveness of Navy undersea manipulator systems. Computer aided controls can be used to improve system effectiveness by performing difficult coordinate transformations to simplify simultaneous movement of joints and by reducing operator task loading by allowing the operator to allocate certain task elements to machine components. Effective use of computers for interactive manned control requires systematic investigation of critical communication factors (e.g., how the operator enters control orders) to determine the structure and mode of command inputs, the proportionment of control functions, and types of feedback denoting system and task status. Initial efforts focus upon a class of control-display elements common to general purpose undersea work systems. Analysis of task requirements and man-machine communication processes is followed by controlled laboratory experiments. Experimental apparatus consists of an advanced design servo-manipulator, programmable computer control system and a CRT display terminal. Algorithms for automatic motion control to specifiable locations within the work envelope have been successfully demonstrated. A command language based on a network of task elements has been defined. The user-defined symbolic commands were found to improve operator performance in a number of simulated manipulation tasks which include sub-task repetitions. Research during the current phase is directed towards investigations of the effectiveness of command language structures and on methods for providing feedback information

through the use of special sensors and graphic displays. This work unit is part of a programmatic research thrust on advanced control/display concepts to improve operator performance with remotely controlled systems. For related research, see also NR 196-150 and NR 196-152. Funding: ONR

Report:

Crooks, W. H., Shaket, E., Chu, Y. & Alperovitch, Y. Man-machine communication in computer-aided manipulation (Tech. Rep. PATR-1034-79-3). Perceptronics, Inc., March 1979.

#### **DISPLAY SYSTEM VARIABLES AFFECTING OPERATOR VIEWING AND CONTROL OF UNDERSEA VEHICLE AND WORK SYSTEMS NR 196-150**

Naval Ocean Systems Center/Pepper

Current Navy submersible work systems, such as CURV (Cable Controlled Undersea Recovery Vehicle) and RUWS (Remote Unmanned Work System), employ standard black and white video (525 line resolution) as the primary viewing system. Operator performance with these systems in turbid water is often limited by lack of adequate cues for depth perception and spatial discrimination. This research is systematically investigating the relationships between operator perceptual/motor performance and properties of an imaging system which affect object differentiation, depth discrimination, spatial orientation and motion resolution. Analytical efforts and experiments are being conducted using components of existing imaging systems and prototypes of advanced viewing systems, including high resolution and stereoscopic systems. The independent variables of primary interest are: (a) task demands;



(b) display system variables; and (c) visibility conditions. Laboratory experiments with conventional and stereo TV systems have provided visual performance data for several types of tasks under a variety of visibility conditions. Current work involves an analysis of motion perception effects on task performance as a result of head movement using stereo display systems. Funding: ONR

Report:

Smith, D. C., Cole, R. E., Merritt, J. O. and Pepper, R. L. Remote operator performance comparing mono and stereo TV displays: The effects of visibility, learning and task factors (Tech. Rep. 380). Naval Ocean Systems Center, February 1979. (AD A068 201)

**RESEARCH ON SUPERVISORY CONTROL OF TELEOPERATORS AND VEHICLES NR 196-152**

Massachusetts Institute of Technology/Sheridan

The principle of supervisory control holds considerable promise for the control or manipulation of mechanical devices. This is especially true for remotely controlled devices (including vehicles). As the name implies, this form of control is largely automatic with the operator intervening, as required to perform interactive monitoring and supervising functions. This research is directed toward establishing general design guides for control systems for the class of future vehicles characterized by undersea teleoperator systems. It seeks to develop models of operator control performance as related to interactive and supervisory control modes. The technical approach includes an examination of environmental constraints and the effects of conflicting sensory cues and delays/distortions in the control loop. Thus far, analytical studies have produced an integrative framework for defining operator functions and for deriving models of supervisory control. Laboratory experiments are being conducted to explicate these models and to examine methods for compensating for distortions in the control loop. Funding: ONR, NMRDC

Report:

Brooks, T. L. Superman: A system for supervisory manipulation and the study of human-computer interactions (Tech. Rep.). Massachusetts Institute of Technology, May 1979.

See also ARCHIVAL PUBLICATIONS: Sheridan, Verplank & Brooks, 1978

**HUMAN ENGINEERING GUIDELINES FOR THE DESIGN OF UNDERWATER DISPLAYS NR 196-157**

Oceanautics, Inc./Vaughan

This work unit is a follow-on to a recently completed research program on underwater vision (NR 196-134) and it serves to transition the research findings to exploratory and advanced development. The objective of this current R & D program is to analyze, interpret and organize the research data on underwater vision and to formulate human engineering guidelines that will support system engineering decisions related to the design of visual displays. One of the most important functions of the data organization is to provide links between physical characteristics of display components and their performance consequences for the visual task being supported by the display in a specific underwater environment (e.g., turbid harbor, near-coastal oceanic water). Illustrative areas of application include instrumentation for wet submersibles, consoles for underwater work systems, hand-held and wrist-worn diver's equipments, and displays on underwater structures. Our research in this domain is responsive to important new requirements for system-to-diver information transfer associated with advances in diving technology. In the past, Navy divers performed their underwater tasks with a minimum of information support. They have been required to feel in the dark, to accomplish a limited range of team tasks according to well-rehearsed procedures and to communicate restricted message sets by means of touch and hand signals. With the introduction of sophisticated mixed-gas breathing equipments, advanced wet submersibles, and complex underwater work systems, information displays are now critical for the diver to control system functions (such as vehicle navigation and operation of sensors) and to monitor life support equipment. However, crucial gaps exist in available handbooks and military design standards for the effective design of underwater displays, particularly with regard to the constraints imposed by dark turbid water and vision through a faceplate. Vaughan, the principal investigator at Oceanautics, is collaborating with Kinney, a distinguished vision scientist at the Naval Submarine Medical Research Laboratory (NSMRL). Kinney is contributing importantly to the interpretation of visual theories

## ENGINEERING PSYCHOLOGY PROGRAMS

and in the formulation of criteria for inclusion in military design standards. Plans are for NAVSEA to provide FY 80 funds for this effort and for the Medical R & D Command to fund the R & D at NSMRL. The Office of the Chief of Naval Operations (Special Warfare Division, OP372G) is providing operational guidance for this program. Funding: ONR

### **ADVANCED DISPLAY CONCEPTS FOR ASW TEAM COORDINATION NR 196-149**

Human Factors Research, Inc./Mackie

New developments in passive sonar technology, in particular towed arrays, improved hull-mounted sonars and the employment of helicopters aboard ASW surface ships, have introduced new dimensions into surface antisubmarine warfare (ASW). The use of multi-mode sensors against multiple targets in ASW presents difficult decision and team coordination problems relating to the processing and display of sensor and tactical information. This research investigates factors underlying the complexities and uncertainties of target detection and tracking as well as counter-detection of own ship. The research examines allocation of functions, data display formats and display methods with the goal of developing human engineering guidelines that will facilitate coordination among team members responsible for sensor system operation and tactical ship maneuvering. Novel methods are being examined for displaying parameters such as threat density and probability, projected target position and effects of alternative maneuvering tactics. Existing data and algorithms are used to simulate environmental, sensor and tactical aspects for representative ASW scenarios. Analytical efforts have identified classes of data and formats (e.g., summaries of probabilistic target position, surveillance coverage and evaluations of trial decisions) which appear promising for future systems. Funding: ONR, NAVSEA

### **MAN-MACHINE INTERACTIONS IN TELECOMMUNICATIONS AND TELECONFERENCING NR 196-135**

The Johns Hopkins University/Chapanis

Telecommunication techniques differ widely in communication richness and costs; they include teletype, voice-alone, voice-plus-video, etc., and can vary in number of nodes, richness of vocabulary, and degree of communication control. As a basis for studying telecommunication systems, this research has studied a set of academic, business, and government meetings exhaustively to determine their communication characteristics and to deduce from them implications for the design of telecommunication systems. The research then investigates the influence of human and system variables on the effectiveness with which humans use telecommunications in solving problems and coming to group decisions, thus providing human performance data as a basis for design tradeoffs. Significant results to date show that voice channels are faster but wordier than teletype; adding video to voice does not improve performance; restricted vocabularies can be as effective as unrestricted; incentives can encourage brevity; and increasing the number of conferees increases communication volume but does not affect task performance time. Funding: ONR

Report:

Brecht, M. A. Study of meeting and conference behavior (Tech. Rep. 8). The Johns Hopkins University, July 1979.

See also ARCHIVAL PUBLICATIONS: Krueger & Chapanis, in press.

### **EFFECTS OF INFORMATION FEEDBACK ON HUMAN ERRORS NR 197-044**

Institute for Behavioral Research/Parsons

A substantial body of research has demonstrated that immediate feedback of information about task performance during training significantly increases the rate of learning. Recent re-analysis of data obtained during the famous "Hawthorne" studies at Western Electric suggests that even highly trained personnel can increase their productivity if they are given continual access to information about their rate of production. This research investigates various types of information feedback as methods of reducing error rates of trained personnel performing cognitive or information processing tasks such as coding, categorizing, error detection and copying. The results are expected to have significant implications for improving productivity. Funding: ONR

## Report:

Parsons, H. M. Variables in human consequence/feedback (Tech. Rep. No. 1) Institute for Behavioral Research, Inc., July 1979. (AD A072 977)

### THE ASSESSMENT OF OPERATOR WORKLOAD IN MAN-MACHINE SYSTEMS NR 196-158

University of Illinois/Wickens

This research is directed at the identification of man-machine factors affecting operator workload and involves both model development and experimentation. The objectives are to: (a) derive reliable methods for predicting dimensions of operator workload based upon attributes of tasks and equipment; (b) establish interrelationships among various workload measures (particularly the way in which these measured co-vary in response to variation of task difficulty); and (c) establish guidelines for predicting interference when tasks are combined. Emphasis is on three classes of tasks - manual control, failure detection and spatial monitoring - required in the operation of command centers and high performance vehicles. Wickens has hypothesized a relationship between these three classes of tasks and "resource reservoirs" in the mental processing system. Each primary task is time-shared with the Sternberg memory search task, and the following variables are manipulated: processing stage (encoding, central processing, responding), processing modality (auditory vs. visual presentation), central processing mode (verbal vs. spatially defined stimuli and memory search) and response mode (verbal vs. manual). Measures are obtained of amount of interference between combinations of tasks at various task loadings, to confirm or refute the existence of the hypothesized reservoirs. In addition, the degrees of independence of auditory, visual, verbal, and spatial perceptual resources in complex multi-element monitoring tasks is investigated. The information processing modeling aspect of this work is being coordinated closely with the research on mental resource allocation in skilled task performance (see cluster B, NR 150-439 and NR 150-441). The design of the validation experiments, particularly with respect to the nature of the tasks and configuration of controls and displays, will derive from a close interaction with

Navy Laboratories such as the Naval Air Test Center. Some of the experiments will be conducted at Navy installations to assess the applicability of the results to operational environments and skilled Naval personnel. Funding: ONR

The following work unit in this cluster was completed during the past year.

### HUMAN FACTORS IN COMPUTER SYSTEMS

NR 196-146

Science Applications, Inc./Ramsey

A comprehensive and critical survey of the literature in selected areas relative to operator-machine factors in computer systems has been completed during the two-year period of this analytic research program. Of the almost 2,000 items examined by this investigator, only about one-quarter were relevant to the quantitative aspects of interactive operator-computer systems; each of those items, with a critical and descriptive annotation, comprise an indexed bibliography which was completed to the year 1977. The items in the bibliography clustered into the categories of properties of the users and tasks, requirements analysis, the use of problem-solving aids, interactive dialogue, input devices and techniques, output devices and techniques, and evaluation procedures. The bibliography demonstrated: (a) the adequacy of the methodologies for analysis, test and evaluation; (b) the concentration of experimental studies into a few, important areas; and (c) the insufficiency of the data bases in those areas for the development of quantitative guides for system design. It was recommended that qualitative prescriptions paralleling the major steps in the design process be developed until norms and standards evolve. Funding: ONR

#### Reports

Ramsey, H.R. Human factors in computer systems: Review of the literature and development of design aids. (Final Rep.) Science Applications, Inc., July 1979. (AD A071 597)

Ramsey, H.R. & Atwood, M.F. Human factors in computer systems: A review of the literature (Tech. Rep. SAI-79-111-DIN) Science Applications, Inc., September 1979

See also ARCHIVAL PUBLICATIONS Ramsey, Atwood & Kirshbaum, 1979

**P. VISUAL AND AUDITORY PERCEPTION**

Vision and audition have been studied for many years and still continue to excite a lot of research activity. Our own research in these areas consists of nine active work units directed at specific issues of potential importance to the Navy. Three investigators (Fox, Rosinski, and Piantanida) are seeking to learn more about how to represent depth in "3-D" visual displays. The solution to such problems will contribute to the utilization of "3-D" in future weapon and vehicle control systems. One investigator (Pachella) is continuing his efforts to understand and facilitate perceptual integration of several dimensions of information in single visual symbols. His examinations will indicate the limits to which one can beneficially combine dimensions in complex signals. Another investigator (Snyder) is examining visual performance and capabilities with advanced electronic displays.

Three work units (Swets, Mackie and Howard) deal with underwater sounds. Swets is working with visual transforms of such sounds. He is seeking to discover the "natural" categories that human observers use when engaging in judgments of similarity and signal identification. Many extant systems require such judgments, and insufficient detailed understanding of the operator limitations at the interface are seen as inhibiting further improvements. Mackie is studying the individual differences among experienced sonar operators engaged in sonar target classification as a basis for the development of a formal model of the task. If successful, the research will establish feasible bases for pre-processing of signals in future sonar systems. Howard is investigating the effects of transient signals upon auditory signal classification with emphasis on the cognitive aspects of the perceptual processes. The potential extension of this work to future passive sonar target classification is both obvious and direct. The final active work unit in this cluster covers the preparation of symposium proceedings for publication. Accounts of five investigations completed during the year round out the report on this cluster.

**INTERACTION OF SOLID FIGURES IN  
VISUAL SPACE NR 197-036**

Vanderbilt University/Fox

Interactions between solid figures in 3-D displays are investigated by stereoscopic techniques, which permit manipulation of the apparent depth of such figures with respect to each other, without introducing potentially confounding changes in other stimulus characteristics. Random dot stereograms are viewed binocularly through filters to create solid figures in space. This mode of depth generation permits the continuous control of apparent depth, the simultaneous use of several figures, and independent stimulus presentations to each eye. Fox has been using a solid ring (which appears as a big doughnut in the 3-D display) surrounding a Landolt ring (which looks like a doughnut with a gap in it). These appear to be at a distance of one to six feet from the observer. Results to date indicate that theories based on the lateral interference between figures in 2-D displays cannot be generalized to the 3-D case. For example, there is an orderly improvement in the number of correct detections of the Landolt gap when the doughnut

appears to be progressively beyond the Landolt gap; but when the doughnut appears to be progressively closer to the observer than the Landolt ring, the percentage of detections over that same distance remains at the same level as that which is observed at the equal depth condition. Experimental design ruled out the role of eye movements and the apparent size of the figures as they were moved toward and away from the observer, as an explanation for the asymmetry in the interference effects. Fox conjectures that the nearer figure, whether it is the doughnut or the Landolt ring, receives a special kind of high-priority processing by the visual system. This "front effect" seems to extend to the temporal domain, where the figure that appears first also receives similar priority. This asymmetry in detection is seen as a general property of visual space that arises from conflict or ambiguity about the visual directions of adjacent signals, and studies continue to explicate that process. These research results indicate to the designer of 3-D displays the extent to which spatial separation of solid figures will have to be maintained to avoid perceptual interference. Funding: ONR

## Report:

Staller, J.D., Lappin, J.S. & Fox, R. Stimulus uncertainty does not affect the time required to perceive stereopsis (Tech. Rep. N14-1101 79C-0002). Vanderbilt University, July 1979. (AD A073 707)

See also ARCHIVAL PUBLICATIONS: Fox, 1978; Shetty, Brodersen & Fox, in press.

### **COMPENSATORY PROCESSES DURING ROTATION OF GRAPHIC DISPLAYS IN SPACE NR 197-042**

University of Pittsburgh/Rosinski

Experience indicates the presence of compensatory processes in human observers that help to preserve the geometric relationships of pictorial forms as the observer shifts away from the normal viewing position anticipated by the display designer. When displayed forms are simple, such as a quadrilateral whose asymmetry depicts its orientation or tilt, there is an expectation that perceptual error in the estimation of orientation will increase with deviation from the correct viewing point. That outcome has been tested by Rosinski with observers viewing the form binocularly and seated at an array of locations in front of and behind the geometrical center of projection (*correct viewing point*) for that form. The judged orientations were in error whether the observers were in front of or behind the correct viewing point, except when the figure was perpendicular to the line of sight. However, the amount of error did not depend on the position of the observer; rather it depended on the degree of tilt of the figure. Rosinski postulates that the outcomes represent a perceptual conflict between the monocular and binocular depth cues, the former pertaining to surface characteristics and the latter to plane orientation. Further, he sees evidence in these experimental data that observers have assumed that a correct viewing point exists which is approximately twice the height of the displayed surface. Studies to clarify the compensatory mechanism and these postulates are underway with an examination of the perceptual effects of lateral shift around the correct viewing point, translation and rotation of graphic forms, judgments of spatial extent, and global assessment of the form structure. These results are of importance to the designer of 3-D displays since they will describe sensitivity of human observers to angular distortions as figures rotate in space. Funding: ONR

## Reports:

Rosinski, R.R. Effects of optical magnification on the perception of displayed orientation (Tech. Rep. 79-1) University of Pittsburgh, March 1979. (AD A065 949)

Rosinski, R.R. & Farber, J. Compensation for viewing point in the perception of pictorial space (Tech. Rep. 79-2) University of Pittsburgh, March 1979. (AD A067 092)

See also ARCHIVAL PUBLICATIONS: Rosinski, 1978; Rosinski & Farber, 1979; Rosinski & Farber, in press.

### **PERCEPTION OF SPATIAL FEATURES WITH STEREOSCOPIC DISPLAYS NR 196-162**

SRI International/Piantanida

Characteristics of binocular depth perception are explored with the aid of a new design of the SRI 3-D eye tracker and visual simulator that allows for independent and simultaneous control of the signals sent to each eye. These studies will determine permissible reductions in the quality of one image of the binocular pair to determine the tradeoffs in bandwidth (needed for resolution and chroma), brightness (needed for contrast), precision of horizontal and vertical registration, and disparities of temporal synchrony for stereo images. Experimental studies are conducted on the limits, interactions, and requirements for depth judgments as the following parameters of the stereoscopic display are systematically varied: luminance, chrominance, contrast, size, rotation, focus, and vertical registration. Experimental outcomes will be utilized to reformulate current theory on binocular depth perception. Funding: ONR

### **PROCESSING OF SYMBOLIC CODES WITH MULTIPLE DIMENSIONS NR 197-035**

University of Michigan/Pachella

The perceptual integration of the physically independent dimensions of a displayed symbol is demonstrated by experimental studies in which human observers assign those symbols into same/different categories. Integrality is achieved when the informational dimensions are no longer perceived as separate dimensions by the observers. Recent experimental evidence gathered by Pachella revises the theory of integrality by showing that

physical dimensions are no longer perceived as distinct dimensions by observers either when those dimensions interact with each other or are not equally discriminable. Interaction is shown when there is a correlation between the physical dimensions. Experiments that introduced interference or redundancy to information processing tasks verified the soundness of that concept of integrality, teased apart the factors of discriminability and interaction among the dimensions, and scaled the perceptual distance between each perceptual dimension. Current studies to refine that concept will specify the requirements that enable perceptual dimensions to emerge and be identified. In addition, significant methodological improvements have been achieved with the development of a multidimensional scaling technique that imposes ordering constraints on each dimension and enhances the interpretation of the perceptual dimensions. The clarification of how observers integrate displayed symbols assists in the design of displays that utilize multiple coding or depict the status of multiple events. Funding: ONR

Reports:

Noma, E. Interession variability and stress. A Monte Carlo study (Tech. Rep. 63). The University of Michigan, June 1979.

Noma, E. & Johnson, J. Constrained nonmetric multidimensional scaling (Tech. Rep. 62). The University of Michigan, June 1979.

Somers, P. Perceptual interaction between stimulus dimensions as a basis of dimensional integrality (Tech. Rep. 61). The University of Michigan, September 1978. (AD A064 867)

See also ARCHIVAL PUBLICATIONS: Pachella & Somers, 1978; Pachella, Somers & Hardzinski, in press; Somers & Pachella, 1978.

### **HUMAN PERFORMANCE WITH ADVANCED ELECTRONIC DISPLAYS NR 196-155**

Virginia Polytechnic Institute and  
State University/Snyder

Displays based on new technologies such as plasma panels, light-emitting diodes (LEDs), liquid crystal displays (LCDs) and head-up displays (HUDs) offer many advantages over traditional cathode-ray tubes (CRTs), but each has unique properties which may constrain the visual performance of the observer. For example, the typical beam splitter

used in HUDs employs a luminance contrast technique which results in inadequate contrast for acceptable legibility under some conditions. This research investigates and quantifies visual performance capabilities and limitations with the new technology displays, and identifies the factors that enhance or constrain effective viewing. Where the constraints might be overcome through alternative design, promising design concepts are tested experimentally. For example, there is evidence that the inadequate contrast of HUDs might be overcome through use of chromatic contrast, at least under high ambient light conditions; the research will quantify the performance trade-offs between luminance and chrominance contrast. A summary of potential naval applications for these displays will be prepared, which will include a description of the limiting conditions for their effective use. Funding: ONR

### **PERCEPTUAL DIMENSIONS IN SIGNAL IDENTIFICATION NR 196-145**

Bolt, Beranek & Newman, Inc./Swets

Visual transforms of underwater sounds are employed to study the perceptual dimensions used by human observers in similarity-judgment and identification tasks. Multidimensional scaling procedures based on judgments of signal similarity yield the main dimensions used in the identification task, but some differences in relevant dimensions were noted between the two kinds of tasks. Observers are seen to change the relative weights they assign the dimensions as conditions of the identification task are changed, e.g., as different subsets of the signals are isolated as the most important, or as signal spacing along various physical dimensions is manipulated to make the dimensions more or less useful. A model of the perceptual and decision behavior during the identification task has been validated with a larger set of spectrographic patterns, and also applied to free-form patterns that are more natural, unitary and organic-appearing, and that have dimensions more difficult to verbalize. Funding: ONR

Reports:

Getty, D.J., Swets, J.B. & Swets, J.A. The observer's use of perceptual dimensions in signal identification (Tech. Rep. 3930). Bolt, Beranek & Newman, Inc., June 1979.

Getty, D.J., Swets, J.A., Swets, J.B. & Green D.M. On the prediction of confusion matrices from similarity judgments (Tech. Rep. 3719) Bolt, Beranek & Newman, Inc., October 1978. (AD A061 683)

See also ARCHIVAL PUBLICATIONS: Getty, Swets, Swets & Green, in press; Getty, Swets & Swets, in press (a), (b).

#### **FACTORS IN AUDITORY SIGNAL CLASSIFICATION BY EXPERIENCED SONAR TECHNICIANS NR 197-060**

Human Factors Research, Inc./Mackie

Recent research studies, establishing feasible bases for the pre-processing of steady-state signals to enhance the target classification task, identified distinctive individual differences among normal listeners in that task. The objective of this research program is to carry that work forward with a population of experienced sonar technicians. Perceptual cue-structure will be determined for the classification of a standard set of underwater sounds and another set of surface-ship sounds, with an increased range of types within each category, and also a set of transient cues. Illustrative features of the acoustic signals that will be examined are fundamental frequency, waveform, signal rise-fall times and periodicity. The data are analyzed by multidimensional scaling techniques to determine the features employed by this special population and to assess the weightings that they apply to each dimension. A formal model is developed from these data that is predictive of performance under the various modes of the classification task. Funding: ONR

#### **PERCEPTUAL PROCESSING OF ACOUSTIC TRANSIENTS NR 196-159**

Catholic University/Howard

Howard is investigating auditory signal classification with an emphasis on the cognitive aspects of the perceptual process. The research examines the role of the listener in imposing rules, filling in structure, and adding other elements for the classification of such a sparse perception as that afforded by a brief, acoustic-transient pattern. Signal pre-processing has become a promising aid for auditory and visual classification and an understanding of the perceptual structure for brief sounds is a step in that direction. Acoustic signals

are generated that simulate transient patterns produced by mechanical equipment in operation, changes in pressures, and other phenomena that are heard in a passive sonar environment. The patterns of acoustic transients are evaluated in a series of experiments that test a bottom-up or feature mode of analysis, versus a top-down or integrated judgment. The influence of consistent vs. competing cues, the sequence of the patterns, the scenario conditions, and type of judgmental responses required, are examined. The effectiveness of performance aids designed around a feature list or a frame list (scenario description) are assessed for significant improvements in classification decisions. The outcomes of these studies will be incorporated into a formal theory of auditory information processing and verified experimentally in sonar classification tasks after the construction of several candidate performance-aiding techniques. Funding: ONR

#### **SYMPOSIUM ON CLASSIFICATION OF AURAL, NON-SPEECH SIGNALS NR 196-154**

Bolt, Beranek & Newman, Inc./Getty

Investigators working in the areas of visual and auditory signal classification, as well as individuals who are developing machine-assisted techniques for the same purpose, were brought together to exchange information on the state of these active disciplines. Sessions were conducted around these themes: (1) performance results with acoustic feature analysis by both operators and machines; (2) recent modifications in theories of aural signal classification; (3) current state of theories of visual signal classification; (4) human performance results with either static or dynamic aural signals; and (5) recent developments in interactive operator-machine systems for classification. Thirteen manuscripts are in various stages of review and revision, and the compilation of indices has been initiated. Arrangements for their publication as a book are firm. Funding: ONR, NSRDC

Report

See ARCHIVAL PUBLICATIONS: Getty & Howard, in press

The following work units in this cluster were completed during the past year.

# UNDERWATER VISION AND VISUAL DISPLAYS FOR THE AMBIENT UNDERSEA ENVIRONMENT NR 196-134

Oceanautics, Inc./Vaughan

For the most part, Navy divers and submersible operators work in murky harbors, rivers, bays, and near-shore coastal oceanic waters. Each of these environments has its characteristic turbidity which scatters natural light and determines the amount and the spectral distribution of light energy at operating depths. In addition, light transmission through the diver's faceplate introduces many troublesome optical distortions. The objective of this research was to investigate the environmental, perceptual and task factors affecting the legibility and design of underwater displays (e.g., instrumentation for wet submersibles, diving equipments). The technical approach included both analytical studies and laboratory experiments. The analytical studies compiled data concerning information transfer requirements, and the environmental and perceptual determinants of display legibility. Five experiments were completed using laboratory simulations of two natural waters as viewing media: nearshore oceanic and inshore harbor/bay waters. In four experiments a variety of visual tasks and display variations were studied in the context of dark, turbid water; in the fifth experiment, the water media were both turbid and illuminated to simulate ambient visual environments during daylight. Experiments 1 and 2 determined the limits of viewing distance for displays of several levels of luminance when water turbidity varied between 10 and 30 parts per million concentration of suspended particles in both "Ocean" and "Harbor" simulations. Experiment 3 determined the limits of the peripheral visual field for signal detection and quantitative reading tasks. Experiment 4 determined display luminance requirements and color appearances of colored displays in dark turbid water; experiment 5 replicated this design using illuminated environments and chromatically-adapted observers. The major findings indicated that display luminance was the dominant display variable affecting legibility in turbid waters. Legibility was a linear function of the logarithm of stimulus intensity; increased concentration of harbor turbidity flattened the slope of the function. Adaptation to homochromatic visual fields had an important and consistent effect on

shifts in color perception. Variation in ocean turbidity was found to be a minor factor in display legibility, while variation in harbor turbidity was a major factor. A coordinated follow-on R&D program (NR 196-157) was initiated during the latter part of this fiscal year with the joint sponsorship of NAVSEA, NMRDC, and ONR. This follow-on effort will transition the research findings to exploratory and advanced development with the goal of analyzing and organizing the research data in the form of human engineering guidelines that will support system engineering decisions. Funding: ONR, NAVSEA

## Reports:

Vaughan, W.S., Glass, R.A. & Williams, J. Peripheral detection and identification of self-luminous display variations in "ocean" and "harbor" viewing environments (Tech. Rep.). Oceanautics, Inc., November 1978. (AD A065 613)

Vaughan, W.S., Glass, R.A. & Williams, J. Luminance requirements and color appearances of colored displays in turbid water: I. Dark ambient viewing environments (Tech. Rep.). Oceanautics, Inc., December 1978. (AD A068 399)

Vaughan, W.S., Glass, R.A. & Williams, J. Luminance requirements and color appearances of colored displays in turbid water: II. Illuminated ambient viewing environments (Tech. Rep.). Oceanautics, Inc., May 1979.

# VISUAL DYNAMICS IN PROCESSING A SERIES OF DISPLAYS NR 197-028

University of Wisconsin/Robinson

Increases in the number of displays within crew stations tend to position some displays further from the direct view of the observer at some penalties in human performance. Over a four-year period, the dynamics of head and eye movements while the operator maintained continuous control of a tracking task were assessed to complete a set of guidelines for the design of such work situations. The timing, velocity, and pattern of head and eye movements were measured as the display in the peripheral visual field changed its level of illumination, location, frequency of change, and other characteristics. The increase in search time requirements for display acquisition was specified when: (a) there was a tracking task present or not, or its difficulty level changed; (b) the format of the display was symbolic or digital, rather than geometric; and (c) the direction of the peripheral



display was known or not. In all of these experimental outcomes, eye-head movements were amenable to more general analysis because they resembled the responses of other human motor-response systems. A sufficient body of data was compiled to develop a set of guidelines for the designers of displays separated by visual angles greater than 0.3 radian (20 degrees) that must be monitored by operators busy at other tasks. Funding: ONR

Report:

Robinson, G.H. Visual dynamics in processing a series of displays: Final Report. University of Wisconsin, September 1978.

See also ARCHIVAL PUBLICATIONS: Nelson, London & Robinson, 1978.

# **SPATIAL ORIENTATION FROM HIGH-VELOCITY BLUR PATTERNS NR 197-034**

University of Nevada/Harrington

Visual perception of peripheral events has been examined over a two-year period with apparatus that could generate and correct for the shape of the peripheral forms that moved at high speeds. The results were verified with experiments where real-world scenes were substituted for the synthetic forms. Normative detection thresholds were established for the curvature, and curvature changes, of blur patterns produced by the moving signals. Such patterns are similar to those seen when moving close to a textured surface; the patterns appear to converge as the surface is approached and diverge as the viewer moves away from it. Data showed that angular displacement of the pattern from the central viewing point was the critical variable and the detectability decreased in a linear fashion. Functional equations were developed for curvature detection with the variates of size, velocity, presence of reference lines and the occurrence of changes in those variables during the presentation. Results of these studies demonstrated that central vision is more sensitive than peripheral, but that observers are sufficiently sensitive to motion in their peripheral vision to assure the adequacy of that mode of signaling. Of operational importance to the design of training simulators is the utility of wide field-of-view visual

scenes with peripheral signals, and the results from this research program have encouraged several users to employ peripheral signaling systems. Developmental aid has been provided for the design of visual flow patterns at the periphery in the V/STOL research simulator and the AWAVS flight simulator at NTEC-Orlando. Funding: ONR

Reports:

Harrington, T.L. & Harrington, M. Spatial orientation from motion-produced blur patterns: Detection of curvature (Tech. Rep. 78-1). University of Nevada, August 1978. (AD A060 300)

Harrington, T.L. & Harrington, M. Spatial orientation from motion-produced blur patterns: Detection of curvature change (Tech. Rep. 78-2). University of Nevada, August 1978. (AD A060 589)

Harrington, T.L., Harrington, M.K., Koh, Y.O., Munson, R.L. & Jacobson, E.M. Spatial orientation from motion-produced blur patterns: Detection of curvature change with reference gratings (Tech. Rep. 78-3). University of Nevada, August 1978. (AD A059 933)

Harrington, T.L. & Harrington, M.K. Spatial orientation from motion-produced blur patterns: Detection of divergence change (Tech. Rep. 78-4). University of Nevada, August 1978. (AD A059 909)

Harrington, T.L. & Harrington, M.K. Perception of motion orientation using divergence, size change, and velocity change (Tech. Rep. 78-5). University of Nevada, August 1978. (AD A060 032)

Harrington, T.L. & Harrington, M.K. Spatial orientation from high velocity blur patterns (Final Report). University of Nevada, August 1978. (AD A060 035)

# **MULTILEVEL THEORY OF VISUAL PERCEPTION AND ITS PERFORMANCE BASES NR 197-039**

University of Michigan/Uttal

In a two-year effort, the literature of perceptual psychology was reviewed and integrated into a set of unifying concepts of visual perception that generalize to other sensory modalities. The model developed from this review consists of six stages of perceptual processing: (a) pre-neural physical transformations; (b) receptor transformations; (c) neural net transformations; (d) unidimensional organizational process of a pre-quantitative nature; (e) multidimensional relational processes leading

to quantitative percepts; and (f) attentive manipulations of the raw perceptual experience from the preceding pre-attentive stages. A manuscript of 12 chapters has been written and reviewed, and final editing is now underway. Arrangements for its publication as a book are firm. Funding: ONR, AFOSR, AFSC(AMD)

Report

Uttal, W.R. The processes of visual perception (Final Report). University of Michigan, September 1979.

See also ARCHIVAL PUBLICATIONS: Uttal, in press.

### **IDENTIFICATION OF PSYCHOLOGICAL FEATURES IN THE RECOGNITION OF COMPLEX NONSPEECH SOUNDS** **NR 197-027**

Catholic University/Howard

Machine-aided visual displays, superior for detection, have been predominant in recent years, but recent advances in auditory information processing recommended a re-examination of the auditory mode for the classification task. In a closely-linked series of experiments extended over four years and aided by the analytic power of multidimensional scaling techniques, the capability of human observers to classify complex underwater sounds was freshly attacked. The identification of the perceptual processes and the relative importance of the various features of the acoustic signals (e.g. fundamental frequency, rise-fall time, periodicity) led to the conclusion that practiced listeners had an improved ability to selectively focus on specific auditory cues in complex signals. Efforts to predict those acoustic features verified that the observers had an internalized set of rules and criteria for the recognition of those features and that they would change with the signal context. The procedure that carries the listener from feature

extraction to the classification decision was explored with a set of synthesized cavitation signals and was demonstrated to be a maximum likelihood process, i.e. categorization is accomplished by features that occur most frequently in the listener's exemplar for that category. A predictive model of this process was tested and found to yield stable results even after extended practice and with listeners of divergent classification skill. Results of these studies have proven useful to NSDRC for the identification of those physical features of own-ship noises that are most detectable by listeners. They have also suggested an approach to selection tests for sonar technicians, and a confirmatory study of this application is being undertaken at Fleet Training Center, San Diego. Funding: ONR

Reports

Howard, J.H., Jr. & Burgy, D.C. Structure-preserving transformations in the comparison of complex steady-state sounds (Tech. Rep. ONR-78-6). The Catholic University of America, December 1978 (AD A066 698)

Howard, J.H., Jr. & Ballas, J.A. Classification of amplitude-modulated noise patterns with extended practice (Tech. Rep. ONR-78-7). The Catholic University of America, December 1978 (AD A066 703)

Ballas, J.A. & Howard, J.H., Jr. Predicting individual listener confusions in the classification of complex, steady-state sounds (Tech. Rep. ONR-78-8). The Catholic University of America, December 1978 (AD A066 704)

Ballas, J.A. & Howard, J.H., Jr. Two approaches to category representation in aural classification (Tech. Rep. ONR-78-9). The Catholic University of America, December 1978. (AD A066 705)

Howard, J.H., Jr. Identification of psychological features in the recognition of complex, non-speech sounds (Final Report ONR-78-10). The Catholic University of America, December 1978 (AD A066 718)

See also ARCHIVAL PUBLICATIONS: Howard & Ballas, in press.

## **Q. INFORMATION PROCESSING AND DECISION MAKING**

The increasing tempo of developing crises, combined with more concentration of control, has resulted in greater risks and uncertainties associated with decisions in modern systems. There has been a growing research interest in how managers, policy makers, military planners and operational commanders might enhance their capability to assess rapidly developing situations and decide upon courses of action. To this end a coordinated ONR/DARPA research program is being pursued to increase our understanding of judgmental biases, inconsistencies and short-cuts that detract from effective decision making, and has

developed models, procedures and computer-based interactive techniques for helping to overcome these natural human limitations. The models have been used to support high level DoD decisions involving resource allocation, contingency planning, system evaluation and intelligence assessment, and are currently being evaluated for use in the World Wide Military Command and Control System. Recently, our research emphasis has shifted to a concern for how people can be helped to generate new alternatives quickly, and how individual differences in decision making style might affect the type of aiding that would prove effective.

Since much of the flexibility in modern systems derives from software, related research is investigating the ease with which computer programs can be generated, de-bugged, modified and maintained by moderately trained personnel. The ultimate objective of this work is to be able to predict programming problems in advance, and provide appropriate interfaces and aids to overcome them.

#### **INTEGRATION OF JUDGMENT THEORY AND DECISION ANALYSIS NR 197-038**

University of Colorado/Hammond

Decision analysis stresses the logical decomposition of a problem into its component parts, the elicitation of probability and utility judgments for each part, and the statistical combination of these judgments to calculate a solution. Judgment theory, on the other hand, relies on holistic judgments made repeatedly under varying problem conditions. The proponents of judgment theory seek to identify the underlying cognitive processes on which decisions are based. These two approaches, and variations of each, have been used successfully in both research and applications, but their commonalities and differences have not been systematically investigated, nor has it been determined whether they produce different results. This research explores the theoretical, methodological and procedural characteristics of decision analysis, judgment theory, and their variants, validates the conclusions experimentally, and provides guidelines for the effective use and integration of the techniques. A comprehensive report describing the various approaches served as a point of departure for a conference among their leading proponents. As one result of the conference a plan was developed to formulate two realistic decision problems and subject them to analysis by practitioners of each approach, to further investigate their commonalities and differences. Funding: ONR

##### **Report:**

Hammond, K., McClelland, G. & Mumpower, J. The Colorado report on the integration of approaches to judgment

and decision making (Tech. Rep. 213). University of Colorado, October 1978. (AD A061 750)

See also ARCHIVAL PUBLICATIONS: Hammond, McClelland & Mumpower, in press.

#### **DATA PLAUSIBILITY AND HYPOTHESIS GENERATION NR 197-040**

University of Oklahoma/Gettys

Research on decision behavior has traditionally sought to understand and model human judgments of uncertainty and utility, and to devise techniques for helping people overcome distortions in judgment which are typically involved in selecting among specified alternatives. In contrast, this particular research addresses an issue which has been largely ignored, namely, how people generate the alternatives in the first place and what factors lead them to expand or reduce the set of alternatives under consideration. Experiments are conducted to test and revise a model of this process. This model assumes that alternatives are generated by a memory search process which is controlled by an assessment process. Results to date indicate that alternatives are then retrieved from memory using part of the available data. These alternatives are then checked for consistency with any remaining data. The set of alternatives thus retrieved from memory is normally impoverished, but when these alternatives are assessed by the decision maker there is a pronounced bias to believe that the set of alternatives is nearly complete, when in fact the set is lacking important alternatives. Several techniques are under investigation which are designed to promote the retrieval of alternatives from memory, and to reduce the bias in the assessment process. Funding: ONR

## ENGINEERING PSYCHOLOGY PROGRAMS

### Reports:

Gettys, C.F., Fisher, S.D. & Mehle, T. Hypothesis generation and plausibility assessment (Tech. Rep. 15-10-78). University of Oklahoma, October 1978. (AD A060 786)

Gettys, C., Mehle, T., Baca, S., Fisher, S. & Manning, C. A memory retrieval aid for hypothesis generation (Tech. Rep. 27-7-79). University of Oklahoma, July 1979. (AD A072 657)

Manning, C., Gettys, C., Nicewander, A., Fisher, S. & Mehle, T. Predicting individual differences in hypothesis generation (Tech. Rep. 28-7-79). University of Oklahoma, July 1979. (AD A072 754)

Fisher, S., Gettys, C., Manning, C., Mehle, T. & Baca, S. Consistency checking in hypothesis generation (Tech. Rep. 29-7-79). University of Oklahoma, July 1979. (AD A072 753)

Mehle, T., Gettys, C., Manning, C., Baca, S. & Fisher, S. The availability explanation of excessive plausibility assessments (Tech. Rep. 30-7-79). University of Oklahoma, July 1979. (AD A072 678)

See also ARCHIVAL PUBLICATIONS: Gettys & Fisher, in press

### **A GOAL DIRECTED APPROACH TO STRUCTURING DECISION PROBLEMS NR 197-049**

University of California-Los Angeles/Pearl

It is generally acknowledged that the way a decision problem is initially formulated has a significant bearing on the solution obtained. This research investigates the formulation of decision problems with particular attention to methods of guiding decision makers toward the discovery of action alternatives they otherwise would not have identified. The approach is to employ a computer-based goal-directed procedure which starts by focusing attention on the objectives to be achieved and the outcomes to be avoided. It then leads the decision maker to identify the uncertainties associated with these goals and the intermediate actions or subgoals which might reduce the related uncertainties. Thus, the method should encourage the proper structuring of decision problems and the generation of alternatives. A formal conceptual model has been devised and is being fully developed into an interactive computer program. A graphic business game system has been completed for experimental investigation of the way people organize, retrieve and generate action alternatives; this system will be used to evaluate the goal-directed approach. Funding: ONR

### Report:

See ARCHIVAL PUBLICATIONS: Pearl, 1979.

### **EFFECTS OF TASK CHARACTERISTICS AND INDIVIDUAL DIFFERENCES ON METHODS OF JUDGING UNCERTAINTY NR 197-050**

Rice University/Howell

In this research it is hypothesized that people make differential use of four kinds of cognitive information when making decisions, depending on the characteristics of the decision task and on their own individual preferences. The four kinds of information are (1) prior knowledge of the data source, (2) intuitive "records" or memories of past occurrences, (3) simplification rules or heuristics, and (4) systematic biases. Experiments are conducted to determine which type of information is used when various types of decision tasks are called for: for example, frequency estimation, prediction over short and long time spans, and choice of actions. The other factors being varied are the kind of event about which the decision is required (repetitive or non-repetitive), the amount of prior knowledge available about the data source, and differences among observers. Preliminary findings show large individual differences in patterns of receptivity to evidence in a frequency estimation task. The results are expected to extend our understanding of the cognitive processes underlying decision behavior. Funding: ONR

### **PSYCHOLOGICAL FOUNDATIONS OF FUZZY SET THEORY NR 197-051**

Decisions and Designs, Inc./Kelly & Weiss

Several decision analytic techniques are available to aid human decision making. Many require judgments in terms more precise than the decision maker can reliably produce. Fuzzy set theory was developed for handling imprecise or ambiguous information. Despite frequent assertions that fuzzy set theory provides a good characterization of human reasoning processes, there has been little empirical research to validate these assertions. This research uses measurement and scaling techniques to investigate the processes by which individuals understand imprecise information. The goal is to produce a numerical scale, consistent with

empirical orderings of degree of set membership, which satisfies the tenets of fuzzy set theory. Initial data show that individuals can order the truth of simple statements in a consistent and transitive manner. Thus, the obtained judgments are consistent with an underlying ordinal representation of partial truth or graded set membership. Further research will use conjoint measurement techniques to provide additional, stronger validation for the obtained scale and to test the generality of the findings. Funding: ONR

Report:

Weiss, J.J., Sticha, P.J. & Donnell, M.L. Preliminary investigations into the psychological foundations of fuzzy reasoning (Tech. Rep. PR 79-9-90). Decisions and Designs, Inc., June 1979. (AD A071 812)

**EXPERIMENTAL EVALUATION OF  
INTERACTIVE DECISION-ANALYTIC  
AIDS NR 197-048**

Perceptronics, Inc./Samet & Christen

To date, the evaluation of decision-analytic techniques has rested largely on user acceptance and testimonials, with few attempts to measure their actual effect on decision performance per se. Ideally, if decision analysis is truly effective, military commanders who use a decision-analytic aid should arrive at a correct decision more often, on the average, than commanders who do not use an aid. This research compares the quality of decision making performance under various amounts and types of aiding, ranging from unaided intuition to guided probability and utility estimation and display involving a minicomputer-based decision aid package. To provide a comparison between decision making in a real-world situation and a fictitious situation, two scenarios have been developed: one scenario is based on realistic developments that might occur in Yugoslavia, and the other is based on a fictitious situation involving a small country beset by internal revolution and foreign intervention. Within each scenario, different message sets have been created to reflect particular states of the world. Through this manipulation of message content and ground-truth, decision performance is being assessed by several objective measures which permit meaningful comparisons among the experimental conditions.

Experienced intelligence analysts are participating in the experiments. Funding: DARPA

**DECISION AND JUDGMENT  
NR 197-058**

Stanford University/Tversky & Kahneman

This research deals with psychological principles that govern human judgment and decision making. Recent studies indicate that individual decision making departs systematically and significantly from the normative model, particularly in the presence of uncertainty or risk. To explain these departures we distinguish two phases in the process of choice: (1) a preliminary process of framing which produces a representation of the acts, their possible outcomes, and the contingencies relating outcomes to acts; (2) a subsequent phase in which these representations are evaluated and the prospect with the highest value is selected. Thus, a decision problem can have several alternative representations—called decision frames—which define the effective choice. The framing of a decision problem depends not only on its natural structure but also on the manner in which it is presented to the decision maker. Because of the nonlinearity of the utility function and the common failure of the expected utility principle, the preference order between prospects is frame-dependent. For example, inconsistencies in choice are found, depending on whether a problem is formulated in terms of lives lost or saved. Three modes of framing are exhibited and their impact on choice is demonstrated: the framing of acts, the framing of outcomes, and the framing of contingencies. This analysis suggests that the quality of decisions could perhaps be improved by a predecision analysis, designed to select a proper decision frame, or at least eliminate some inappropriate ones. The present research provides some of the basic conceptual tools that are required for such an analysis. The concept of a decision frame can be extended to the effect of an agenda, or other external constraint, imposed on the choice set. It is shown that the manner in which options are grouped and the sequence in which they are considered have a predictable impact on choice. The effects of an agenda are investigated, from both experimental and theoretical standpoints, using a probabilistic choice model based on a tree structure. Dr. Kahneman, at the

University of British Columbia, is an Associate Investigator. Funding: ONR

Report:

See ARCHIVAL PUBLICATIONS: Tversky & Sattath, in press.

**DECISION ANALYSIS AND BEHAVIORAL DECISION THEORY NR 197-061**

University of Southern California/Edwards

The past decade has witnessed a significant increase in research and methodological development concerned with understanding human decision behavior. Techniques for helping people avoid typical errors in judgment have taken a variety of forms, and have been applied in many military, business, and public policy decision situations. This effort will result in a book that integrates and describes the research findings and their underlying theoretical structure, and provides examples of applications taken from military command and control, intelligence analysis, and other contexts. A fourteen-chapter book, in three parts, has been outlined in detail. A two-year effort is devoted to preparation of material covering the following topics: elements of decision analysis (decision problems, simple and complex models, a historical perspective); decision structures and their parts (problem structuring, judgmental probability measurement, inference models, value and utility measurement, value, utility and risk models, insensitivity and flatness); confronting the analysis with the real world (groups and organizations, applications for inference, diagnosis, evaluation and decision making). Funding: ONR, ARI

**CONTROLLED ENVIRONMENT EXPERIMENTS ON THE DECISION TEMPLATE CONCEPT NR 197-052**

Decisions and Designs, Inc./Gulick

The purpose of this research project is to conduct a series of controlled environment experiments to demonstrate and evaluate a computer-based decision aid for possible incorporation into the World Wide Military Command and Control System (WWMCCS), to support the National Military Command Center and similar staff operational functions. The project consists of developing a

decision template concept, producing a demonstration and evaluation plan, developing crisis scenarios, creating training materials and methods, producing computer software, presenting briefings, running demonstrations, training subjects, and developing specifications for an improved decision aid which will be implemented eventually by two geographically dispersed command centers simultaneously. Templating is a formal procedure for structuring the judgments which would normally be made by a military staff in times of crisis decision making. It requires that the staff identify viable alternative courses of action, consider various uncertainties which could affect the consequences of choosing any particular course of action, describe explicitly the consequences associated with each course of action and each possible outcome, identify criteria against which these consequences will be evaluated, and encode these consequences and key uncertainties numerically so that sensitivity analyses can be carried out to develop a recommended course of action. While some of these steps could be carried out intuitively or using pencil and paper methods, the implementation of the templating procedure using a computer provides several advantages. First, the computer repeatedly performs the calculations necessary to evaluate each possible course of action, thereby testing, at the direction of the user, the effect of changes in the inputs. In addition, the computer program acts as a recording device as a decision problem is structured, by keeping track of and displaying the lists of options, outcomes, and value dimensions. The user types the problem description into the computer in response to questions posed by the computer program and thus, in addition to recording the problem structure, it also facilitates the development of the problem structure. Findings to date show that the decision templating procedure facilitates communication among different elements of a military staff. They know not only precisely where it is that they disagree, but also by how much and what difference it might make. This enhanced communication among staff elements facilitates battle staff integration and reduces the likelihood of critical misunderstandings. In addition, by organizing the dialogue and debate among the crisis management cell members, it substantially speeds up the process of developing a recommendation so that the staff is not overtaken by events. Funding: DCA

## Report:

Kelly, C.W. & Gulick, R.M. Decision template concept: Demonstration plan and status report (Tech. Rep. PR 79-10-99). Decisions and Designs, Inc., June 1979.

## DOCUMENTATION OF DECISION AIDING SOFTWARE PACKAGES NR 197-053

Decisions and Designs, Inc./Kelly

Over the past six years, a variety of decision-aiding techniques and the software packages to implement them have been developed, tested, and refined into highly utilitarian form under the ARPA-supported Advanced Decision Technology Program. These software packages are, for the most part, generic in nature and, hence, can be applied by users to a wide variety of structurally similar decision problems. Classes of decision problems to which one or more of the software packages apply include: comparative evaluation of alternative system configurations, rapid option assessment, cost-benefit analyses and zero-based budgeting. The various software packages were programmed in the APL language to run on the IBM 5100 computer. In this configuration, the software packages were tested in many DoD decision contexts by DoD users who were specifically trained in the use of the software packages by contractor personnel. While the software/hardware configuration and detailed user training requirements were appropriate to the development and test phase of the products, neither the present APL implementation of the models nor the requirement for direct tutorial assistance in their use are suitable conditions for the further dissemination and use of these decision-aiding packages. IBM 5100 computers are not in general use in DoD. The APL programming language is not in the repertoire of the majority of DoD programmers, and the requirement for personal tutorial assistance to an extended user population would not be cost-effective. To achieve the desired objective of delivery of information and new technology of general utility to a diverse DoD user population, there was a need to prepare a carefully executed set of instruction material, user manuals, and software code that will enable diverse users having varied levels of skill in the subject matter to: (a) select the software package appropriate to the decision problem at hand, (b) understand the concepts underlying the model and the operations

required to implement it, and (c) implement the models on the computer configuration available to the user. This project will develop a multi-tiered documentation package including: an introductory guide to the set of decision analytic software packages, user guides for each package, as well as a functional description and system specification for each. These elements of documentation will be in sufficient detail to permit a software production house to generate essential program specifications, FORTRAN or COBOL code and program maintenance documents, and to enable users to readily apply the decision analytic software packages. The completed documentation will address six separate software decision aids. Funding: DARPA

## Reports:

Amey, D.M., Feuerwerger, P.H. & Gulick, R.M. Documentation of decision-aiding software: INFER functional description. Decisions and Designs, Inc., June 1979.

Amey, D.M., Feuerwerger, P.H. & Gulick, R.M. Documentation of decision-aiding software: INFER system specification. Decisions and Designs, Inc., June 1979.

Amey, D.M., Feuerwerger, P.H. & Gulick, R.M. Documentation of decision-aiding software: INFER users manual. Decisions and Designs, Inc., June 1979.

Amey, D.M., Feuerwerger, P.H. & Gulick, R.M. Documentation of decision-aiding software: OPINT functional description. Decisions and Designs, Inc., April 1979.

Amey, D.M., Feuerwerger, P.H. & Gulick, R.M. Documentation of decision-aiding software: OPINT system specification. Decisions and Designs, Inc., April 1979.

Amey, D.M., Feuerwerger, P.H. & Gulick, R.M. Documentation of decision-aiding software: OPINT users manual. Decisions and Designs, Inc., April 1979.

## RESEARCH ON THE THEORY AND APPLICATION OF DECISION ANALYSIS

NR 197-054

Stanford University, et al

This is the first of four components of a DARPA-funded program to fill knowledge gaps in decision theory and improve decision analytic techniques. This component investigates decision structure encoding, analytic resiliency, and information perishing and decay. Structure encoding procedures are developed to help individuals formulate their ideas in the form of mathematical models.

Methods are developed for determining the sensitivity of decision analysis results to reasonable changes in the alternatives, information, and preference which went into the analysis. Models are developed of the information acquisition process, the dynamic characteristics of the system, and the way in which a delay adversely affects the outcomes. Funding: DARPA

Report:

See ARCHIVAL PUBLICATIONS: Howard, in press.

**VALIDATION, ERROR AND SIMPLICITY OF  
DECISION TECHNOLOGY NR 197-055**  
University of Southern California/Edwards

This is the second component of the DARPA-funded program. Theoretical development, experimentation, and simulation studies are conducted to investigate the issues: (1) validation of decision analytic structures, especially utilities, and (2) the extent to which variability in human judgment implies the possibility of simplifying techniques for eliciting judgments. In the validation studies, the effects of elicitation method and amount of training or experience in utility functions are determined. Efforts are made to obtain "ground truth" in utility judgments by using bank credit application scoring models as criteria against which to measure bank officers' judgments. Both simulation and experimental methods are used to determine appropriate tradeoffs between judgmental error and modeling error. It is hypothesized that for most problems a relatively simple elicitation technique is not only adequate but preferable. Funding: DARPA

**BEHAVIORAL RESEARCH IN DECISION  
AIDING NR 197-056**  
Perceptronics, Inc./Slovic

This third component of the DARPA-funded program addresses issues related to understanding and improving intuitive judgment. Previous research has identified several types and sources of bias in judgments; this effort develops several debiasing procedures, such as novel elicitation techniques, and tests them experimentally. Theoretical and experimental work is conducted to develop and extend the implications of Prospect Theory, which

emphasizes the differential effects of gains and losses (rather than total assets) and the degree of certainty about outcome probabilities, in subjective utility assessment. A review is conducted of research literature dealing with discrepancies between contingency planning decisions and the decisions made when the event actually occurs. Implications are drawn for planning behavior and for decision analysis methods. Funding: DARPA

Report:

See ARCHIVAL PUBLICATIONS: Bar-Hillel, in press; Fischhoff, in press (a), (b); Fischhoff, Slovic & Lichtenstein, in press; Koriati, Lichtenstein & Fischhoff, in press.

**RESEARCH ON DECISION PROBLEM  
STRUCTURING NR 197-057**  
Decisions and Designs, Inc./Kelly

This fourth component of the DARPA-funded program began by examining motives and means for injecting creativity into decision structuring. It found that the logical nature of decision analysis can be improved upon by creating a balance between preceptive and receptive information gathering, by bringing both systematic and intuitive information evaluation into play, and by avoiding specific perceptual blocks to creative decision analysis. Particularly, visual imagery is an extremely important tool in conceptualization. Effort is being directed toward studying methods for incorporating visual problem structuring into decision analysis. An advanced computer-video display and image processor will be used in this effort. The study has indicated two philosophical poles concerning the structuring of decision-analytic models. The engineering science approach uses complex, engineering-like models to link the decision maker's alternatives to his value structure; a computer then calculates the decision-analytic answer. The clinical art approach develops a simple model that structures the decision maker's thoughts concerning a decision in such a way that the critical issues in choosing one alternative over another are readily apparent. The study asks whether the decision analyst's environment may be characterized in a way that highlights the circumstances under which each polar approach is favored in decision problem structuring. Computer-assisted problem-structuring software, largely oriented to the clinical art approach, is



being produced. Three computerized aids are being produced, with different emphasis in applications, methods, and users. Funding: DARPA

**REPRESENTATION OF INFORMATION IN SOFTWARE DOCUMENTATION**

**NR 196-160**

General Electric Company/Curtis

Experimental analysis of the differential value of current and proposed software documentation techniques is pursued. Such techniques aid programmers and reduce life cycle costs in software development. Nine candidate forms of documentation combine three forms of representation (ideograms, constrained language, and narrative) and three forms of ordering (sequential, branching and distributed). Three broad classes of program types matched for complexity are employed. Initial studies examine the process of program comprehension in which a program function is reconstructed. Later experiments assess the coding, compiling, and debugging of program modules. Theoretical issues on information handling that underlie programmer performance are clarified by the outcomes of these studies. Funding: ONR

**SOFTWARE DEVELOPMENT UNDER INCREASING LEVELS OF AUTOMATIC PROCESSING**

**NR 196-161**

Performance Measurement Associates, Inc./Connelly

This research investigates the capability of programmers of varied skill level to specify software programs for problems of different levels of complexity. The primary independent variable is the availability of several degrees of automatic processing support which provide corresponding amounts of flexibility to the user. The level of difficulty of each problem is reflected in the number of steps needed by the user to develop a solution to the overall problem. The tasks of the user include searching, reading, matching, and computing of statistics from card files, which when linked together will help solve a wide range of complex problems (e.g., allocation of task force resources). The machine processing of the user inputs permits inferences about which algorithm is required to

solve a particular problem and the iterative feedback of test data leads to a precise definition of the desired program. Based on these experiments the investigator develops concepts for feedback aids in program generation. Funding: ONR

**SYMPOSIUM ON ATTENTION AND PERFORMANCE NR 197-047**

Bolt, Beranek & Newman, Inc./Nickerson

An invitational conference presented and assessed aspects of human information processing that impact on attention and performance. Papers were given on: the influence of antecedent conditions, such as muscular tension, on skilled movements; short-term memory for complex motor activities; the allocation and control of attention in multiple task situations; response tendencies that arise from sequential events in signal identification; temporal organization of perceptual skills during continuous visual search; attentive elements and retrieval skills that improve language comprehension and problem solving; and the refinement of the distinctions between problem solving and decision making. Thirty-eight manuscripts are in various stages of review and revision. Arrangements for their publication as a book have been completed. Funding: ONR, ARI, NSF

Report:

See ARCHIVAL PUBLICATIONS: Nickerson, in press.

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The following work units in this cluster were completed during the past year.

**ADVANCED DECISION TECHNOLOGY NR 197-045**

Decisions and Designs, Inc./Kelly

In a multi-contractor program of basic and applied research, investigations were conducted over a period of two years to increase our understanding of human decision behavior and to design, evaluate and transfer advanced decision-aiding technologies to operational use. The effort was built upon several years of preliminary research results, and it included educational and applied problem-solving assistance provided to senior civilian and govern-

## ENGINEERING PSYCHOLOGY PROGRAMS

ment officials. During the past year such assistance was provided to the Central Intelligence Agency, the U.S. European Command, Headquarters-U.S. Marine Corps, and the U.S. Army Staff. The research effort contributed several significant advances to the body of knowledge concerning human decision making processes. Advances were also made in how decision makers should reconcile incoherent personal judgments, and how they interpret a stream of diverse and conflictual events and their relationships to primary uncertainties in the decision process. Decisions and Designs, Inc., was the prime contractor, responsible for coordinating the work of contributing contractors, for conducting the educational and applied problem-solving, and for performing some of the basic research. The following organizations and principal investigators contributed to the research effort under sub-contracts: Dr. Ward Edwards (University of Southern California), Dr. Paul Slovic (Decision Research, A Branch of Perceptronics, Inc.), Dr. Ronald Howard (Stanford University), Dr. Howard Raiffa (Harvard University) and Dr. M.W. Merkhofer (SRI International). Results of this research, and the related pilot applications, are reported in the documents listed below. Funding: DARPA, NSWC, ARI

### Reports

Brown, R.V. & Lindley, D.V. Reconciling incoherent judgments (RIJ) Toward principles of personal rationality (Tech. Rep. TR 78-8-72). Decisions and Designs Inc., July 1978. (AD A059 639)

Buede, D.M., Donnell, M.L., Feuerwerger, P.H. & Ragland, J.E. Applications of decision analysis to the U.S. Army affordability study (Tech. Rep. TR 78-10-72). Decisions and Designs, Inc., December 1978. (AD A064 442)

Buede, D.M. & Ragland, J.E. Cost-benefit analysis applied to the program objectives memorandum (POM) (Tech. Rep. TR 78-9-72). Decisions and Designs, Inc., November 1978. (AD A063 619)

Edwards, W., John, R.S. & Stillwell, W., Research on the technology of inference and decision (Final Rep. No. 001922). University of Southern California, January 1979.

Fischhoff, B. & Fulero, S. What makes a good explanation? (Tech. Rep. PTR-1060-77-11). Decision Research, November 1977 (AD A056 668)

Fischhoff, B., Slovic, P. & Lichtenstein, S. Improving intuitive judgments by subjective sensitivity analysis (Tech. Rep. PTR 1060-78-7). Decision Research, July 1978. (AD A058 998)

Fischhoff, B. & Slovic, P. A little learning... Confidence in multicue judgment tasks (Tech. Rep. PTR-1060-78-6). Decision Research, June 1978. (AD A059 147)

Shaklee, H. & Fischhoff, B. Discounting in multicausal attribution: The principle of minimal causation (Tech. Rep. PTR-1060-78-8). Decision Research, August 1978. (AD A065 142)

See also ARCHIVAL PUBLICATIONS. Howard, 1978; Howard, Matheson & Owen, 1978; Owen, D., 1978; Owen, P., 1978; Fischhoff, Slovic & Lichtenstein, 1979; Fischhoff, in press; Fischhoff & Slovic, in press.

## DECISIONS UNDER CONDITIONS OF UNCERTAINTY NR 197-032X

University of Washington/Mitchell & Beach

These investigators created a decision making contingency model in which strategy selection is contingent upon a compromise between the decision maker's desire to make a correct decision and his or her negative feelings about investing time and effort in the decision making process. The desire to be correct is seen as contingent upon the demands of the task environment and imposed time and money constraints reduce the number of strategies that can be selected. The choice of a strategy also reflects the decision maker's characteristics, particularly knowledge of, and faith in, the various strategies as well as his or her opinion about the resources they each require for implementation. The decision maker's knowledge determines the strategies in the repertory, while faith can be seen as the decision maker's perception of the probability that each strategy could lead to a correct decision if it were selected. The estimated resource requirement is the price the decision maker thinks will have to be paid to use any particular strategy. The strategy that is perceived as yielding the maximum net gain is the one selected; one that costs more would be a bad investment of resources and one that costs less would unnecessarily increase the risk of an incorrect decision. A number of laboratory experiments were completed which provide support for the model. Funding: ONR

### Reports

Larson, J.R. Jr. & Reenan, A. M. The equivalence interval as a measure of uncertainty (Tech. Rep. No. 77-9). University of Washington, March 1978. (AD A056 949)

Weed, S.F. & Mitchell, I.R. The role of environmental and behavioral uncertainty as a moderator of situational

## ENGINEERING PSYCHOLOGY PROGRAMS

performance relationships (Tech. Rep. No. 78-15). University of Washington, June 1978. (AD A056 950)

McAllister, D.W., Mitchell, T.R. & Beach, L.R. The contingency model for the selection of decision strategies: An empirical test (Tech. Rep. 78-17). University of Washington, October 1978.

### **PSYCHOLOGICAL COMPLEXITY OF COMPUTER SOFTWARE PROGRAMS NR 197-037**

General Electric Company/Love

Software quality and complexity critically determine developmental, operational, and maintenance costs for computer programs. This work unit sought quantitative specification of those characteristics over the past two years. Three promising metrics were experimentally evaluated: (a) Halstead E - based on ratio of the number of different operators and operands in the code; (b) McCabe v(G) - based on the number of control paths in the code; and (c) number of lines of code. Those measures were examined under well-controlled conditions, with several categories of programmer skill-level, on the principal tasks of constructing, understanding, modifying, and debugging lines of code. Programmer performance was assessed by the amount of working time, error occurrence, and skill-level requirements. It was demonstrated that the Halstead E metric is a valid measure of software complexity that correlates with the various indices of programmer performance. The metric is also supportive for a theory of software

science that incorporates human performance concepts. Of no small importance is the refinement of methodology and clarification of important variables which will facilitate the development of other research programs toward an understanding of computer programmer tasks. Of operational significance is the verification of a software package for the E metric that will assess software complexity. That software program has already been employed by some commercial firms as a guide for achieving software quality. The results are also being brought to the attention of computer scientists in the Marine Corps who are making decisions regarding software for future systems; they include personnel in Marine Corps activities ranging from Headquarters to automated services center and development activities. Funding: ONR

#### Reports

Sheppard, S.B., Milliman, P. & Curtis, B. Factors affecting programmer performance in a debugging task (Tech. Rep. 79-388100-5). General Electric Company, February 1979. (AD A068 196)

Curtis, B. & Sheppard, S.B. Identification and validation of quantitative measures of the psychological complexity of software (Final Tech. Rep. 79-388100-7). General Electric Company, April 1979. (AD A072 547)

See also ARCHIVAL PUBLICATIONS: Curtis, Sheppard, Borst, Milliman & Love, 1978; Curtis, Sheppard & Milliman, 1979; Curtis, Sheppard, Milliman, Borst & Love, 1979; Love & Curtis, 1979; Sheppard, 1978; Sheppard, Borst, Curtis & Love, 1978; Sheppard, Curtis, Milliman, Borst & Love, 1979; Sheppard, Curtis, Milliman & Love, in press.

## **R. DECISION AID DEVELOPMENT**

This cluster consists of two projects, one (the NR 199 series) is 6.2 funded, and the other (the NR 198 series) is 6.3 funded. Both seek to expand the techniques available to decision makers and to promote their application in a wide variety of Navy and Marine Corps command and control systems. The first three work units constitute the exploratory development project, Decision Support, in which major types of decisions made in naval units and in Marine Corps tactical combat operations are characterized; these taxonomies are forming a basis for identifying and developing appropriate supporting techniques and evaluating their effectiveness. The remainder of the work units (NR 198 series) comprise a multi-disciplinary advanced development project, Operational Decision Aids, in which advanced computer science, decision analysis, and tactical engagement models are integrated with interactive graphics to aid in Naval task force command level decisions. Scientific monitoring of this project is shared with other program areas in ONR, which are cited as appropriate.

**A TAXONOMIC METHOD FOR  
CHARACTERIZING NAVY COMMAND AND  
CONTROL DECISIONS NR 199-001**

Applied Decision Analysis, Inc./Miller

Major types of decisions made in Navy command and control systems at the unit, task force and fleet command levels are identified and characterized with regard to level of command, type of warfare, function accomplished, and context or time horizon. A taxonomy of relevant characteristics is developed, incorporating features such as time dependence, information uncertainty, complexity, and the stakes involved. Appropriate decision supporting techniques are identified and characterized with regard to data processing and storage capability, complexity of the user interface, and cost. Preliminary guidelines are prepared for utilizing and evaluating the supportive technology. Funding: ONR

Report

Miller, A.C., Rice, T.R. & Metcalfe, M.R. An analytical characterization of Navy command and control decisions (Tech. Rep.). Applied Decision Analysis, March 1979. (AD A069 124)

**A TAXONOMIC METHOD FOR CHARAC-  
TERIZING MARINE CORPS COMMAND  
AND CONTROL DECISIONS  
NR 199-002**

Perceptronics, Inc./Saleh

This effort, similar in nature to NR 199-001, focuses on Marine Corps command and control decisions. Major decisions made in Marine Amphibious Brigade (MAB) operations are identified and characterized. A two-way taxonomy of MAB decision situations is then established along a decision-task dimension and decision-maker dimension. A taxonomy of decision support techniques including decision analysis, artificial intelligence, pattern recognition, user-oriented graphics and interactive displays is developed. Principles for matching decision situations and decision support techniques are then defined. Funding: ONR

Report

Crotte, A., Saleh, J. & Brown, J. Development of a tactical decision task taxonomy for the Marine Corps command and control environment (Tech. Rep. PFR 1069-79-6) Perceptronics, Inc., June 1979

**DECISION AIDS FOR NAVAL AIR ASW  
NR 199-003**

Analytics/Strieh

Critical decision situations encountered by aircrews on ASW platforms operational in the 1980-85 time frame are identified from process flow and task analyses of the ASW mission. The situations are prioritized based upon a measure of merit that incorporates decision task complexity and mission segment interdependencies. Confirmation of the prioritizations is obtained from the operational community, and a multi-dimensional scaling technique is employed to determine the dimensions used by operational personnel in establishing priorities. A taxonomy of decision techniques is developed and matched against the characteristics of each decision situation. The resulting matrices specify the decision aiding technologies that can be applied to each situation and their probable complexity. Specific design features are developed for one selected high priority aid. Funding: ONR, NADC

**DESIGN OF A COMPUTATIONAL TEST BED  
FACILITY FOR EVALUATING OPERATION-  
AL DECISION AIDS NR 198-004X**

University of Pennsylvania/Hurst

This effort has two objectives. The first is to investigate the applicability of advanced computer software technologies as components of a decision aiding system. The following features have been examined and demonstrated: a flexible alerting and triggering capability; a natural English language query system; a method for user control of display partitioning and display characteristics, with automatic expansion of display windows when necessary. The second objective is to establish a test bed facility in which all the techniques being developed in this project can be incorporated and evaluated, singly and integrally, using a simulated tactical warfare scenario. For this task, advanced graphics display terminals have been programmed with features such as paging, and integrated with standard alphanumeric terminal devices. In the past year the first experimental evaluation of an aid has been performed using 66 subjects under a variety of aid conditions. This research is monitored by the Information Systems Programs of the Mathematical and Information Sciences Division. Funding: ONR

## Reports

Buneman, P.O. & Beyer, F. A space efficient dynamic allocation algorithm for queuing messages (Tech. Rep. 79-01-04) University of Pennsylvania, January 1979. (AD A067 602)

Hackathorn, R.D. Exploring the concept of a codasyl database machine (Tech. Rep. 78-12-04) University of Pennsylvania, January 1979. (AD A067 249)

Flam, J.J. Model management systems: A framework for development (Tech. Rep. 79-02-04) University of Pennsylvania, February 1979. (AD A067 246)

Ribeiro, J.S. DBALFRT: An altering system for WAND (Tech. Rep. 78-12-02) University of Pennsylvania, December 1978. (AD A067 247)

See also ARCHIVAL PUBLICATIONS: Buneman & Beyer, in press.

### MATHEMATICAL DECISION AIDS NR 198-007X

Decision-Science Applications, Inc./Noble

The electronic warfare area was identified as a promising area for development of mathematical decision aids, and a prototype aid has been developed which addresses the problem of emissions control (EMCON) planning. The aid, which is now undergoing psychological testing, includes a wide variety of displays which assist the planner in assessing: the information given away by Task Force radar emissions, the quality of radar surveillance coverage, and the trade-off between information given away and air defense surveillance performance within the context of postulated threat scenarios. The research is monitored by the Operations Research Programs of the Mathematical and Information Sciences Division. Funding: ONR

## Report

Densmore, J.E., Kerchner, R.M., Noble, D.E., Page, G.E., & Tomlinson, P.G. An emissions control decision aid (Vol. I) (Tech. Rep. DSA-66) Decision-Science Applications, Inc., July 1978. (AD A060 072)

### OPERATOR-AIDED OPTIMIZATION TECHNIQUES FOR TACTICAL DECISIONS NR 198-010

Integrated Sciences Corp./Walsh

Methods are investigated to determine the most efficient mix of human judgment and computer calculation capabilities in the selection of an air strike path to a target through an enemy sensor field. Two types of optimizing algorithms have already been investigated, one based on dynamic programming, the other on nonlinear programming. In both cases the human could enter approximate solutions and constraints to the solution space. Experimental results showed that operators using the nonlinear programming aid did significantly better than those without the aid, the improvement averaging 29%, and that variance was significantly reduced with the aid. Operator-aided optimization was also better than complete automation, since the machine working alone tended to find local instead of global solutions. Current work is focusing on comparison of interactive manual optimization, in which the computer is used to calculate the value of the operator's successive trial solutions, with operator aided optimization. Funding: ONR

## Report

Walsh, D.H. & Schneidman, M.D. An investigation of selected alternative decision aids (Tech. Rep. 215-8) Integrated Sciences Corporation, April 1979. (AD A070 824)

### NOMOGRAPH DECISION AIDS NR 198-017X

Analytics/Epstein

An interactive model with appropriate displays has been developed to aid in deciding upon the best time to launch an air strike, as a function of changes in own aircraft availability, enemy defenses, and weather, with estimated own losses and enemy destruction as criteria. This is regarded as a prototype of a more general concept for aiding in the choice of the best time to initiate a previously selected action. Methods of displaying the critical variables and the expected values and variances of the possible outcomes have been investigated. The aid has been configured for experimental testing and experimental decision problems and training materials have been developed. An experiment was conducted to compare aided with unaided decision making, using the experimental decision problems. Methods have been developed for integrating this aid with aids which address other facets of air strike planning such as strike path selection and force composition for sequential

operations. This research is monitored by the Naval Analysis Programs of the Mathematical and Information Sciences Division. Funding: ONR

Report:

Glenn, F. & Zachary, W. Integration of decision aids for strike campaign planning (Tech. Rep. 1344-C). Analytics, May 1979. (AD A069 751)

See also ARCHIVAL PUBLICATIONS: Epstein, in press.

**EVALUATION CRITERIA, EXPERIMENTAL DESIGNS AND PERFORMANCE MEASURES FOR DECISION AIDS NR 198-018**

Applied Psychological Services, Inc./Siegel

Independent objective evaluations are conducted of the decision aids being developed by other contractors on the Operational Decision Aids project. This effort includes development of recommended criteria, experimental designs, performance measurements and data analyses, well as actual conduct of the formal experiments in the University of Pennsylvania test bed. Experimental evaluations of two aids have been conducted and results are being analyzed. Funding: ONR

Reports:

Siegel, A. I. Operational decision aid evaluations (Annual Report). Applied Psychological Services, Inc., July 1978. (AD A064 297)

Siegel, A. I. & Madden, E. G. Decision aid evaluation program (Annual Report). Applied Psychological Services, Inc., June 1979. (AD A070 705)

The following work units in this cluster were completed during the past year

**APPLICATION OF DECISION ANALYSIS TECHNOLOGY TO OPERATIONAL DECISION AIDING AT THE TASK FORCE COMMAND LEVEL NR 198-002**

Decisions and Designs, Inc./Peterson

This was one of the first research efforts under the Operational Decision Aids project. Its objective was to determine the effectiveness of decision analytic procedures to support tactical decisions at the task force command level. It was found that two

types of models could be effectively employed: (1) a Bayesian inference model to assess a threat situation, and (2) a multi-attribute utility model to help choose a course of action contingent on the assessed situation. The two models could be combined, so that if a decision problem was analyzed in advance, a set of decision rules could be developed for rapid use during operations. A display was developed which showed the user how the situation assessment changes as new information enters the system, and provided a continuous dynamic indication of the best course of action at any given time. Simulation studies showed the desirability of modifying the Bayesian model to take account of data dependencies and of changes in enemy intentions. Informal evaluation of the models and displays, using experienced Naval officers, showed that many found the displays and procedures compatible with their own thought processes, but several found the required probability and utility judgments burdensome. In general, the situation assessment aid was found more useful than the action choice aid. Funding: ONR

Report:

Barclay, S., Peterson, C. R., Randall, L. S. & Donnell, M. L. Decision analysis as an element in an operational decision aiding system: Phase V (Tech. Rep. PT 78-29-6). Decisions and Designs, Inc., April 1979. (AD A068 339)

**TASK FORCE DECISION ENVIRONMENT AND DECISION AIDS NR 198-003X**

SRI International/Garnero

The Naval Task Force decision environment was analyzed, two warfare scenarios were developed to serve as bases for simulation experiments, and potential decision aids were identified. An engagement model or outcome calculator was developed which provides a rapid estimate of air strike effectiveness as well as losses for various offensive and defensive force mixes which might be considered during strike planning. Improvements to the internal model structure were made, tests for possible inconsistencies of internal logic were conducted, and revisions were made to enhance its usefulness and acceptability in the fleet environment. The outcome calculator is now being incorporated into an integrated air strike planning aid. This research was monitored by the Naval Analysis Programs of the Mathematical and Information Sciences Division. Funding: ONR

## Reports:

Garnero, R.S., Rowney, J.V. & Ketchel, J. Evolution and preliminary tests of the strike outcome calculator (SOC) (Tech. Rep. NWRC TR-16). SRI International, October 1978. (AD A061 364)

Garnero, R.S., Bobick, J.C. & Ayers, D. Strike outcome calculator (SOC) — description, and operating instructions (Tech. Rep. NWRC TR-15). SRI International, March 1978. (AD A061 363)

**INTERACTIVE AIDS FOR STRUCTURING  
AND ANALYZING DECISIONS NR 198-009**  
SRI International/Merkhofer

A computer-assisted, step-by-step procedure was developed for establishing the basic structure of a decision problem. Initial steps in the procedure elicit a preliminary overall decision structure. Subsequent steps are designed to identify and expand the analysis of those areas to which the decision is most sensitive. An interactive computer program with graphics for implementing the procedure was partially developed prior to completion of this contract. It is intended that the program be completed and evaluated experimentally, using typical warfare scenarios, as soon as permitted by available resources. Funding: ONR

## Report

Merkhofer, M.W., Robinson, B.F. & Korsan, R.J. A computer aided decision structuring process (Final Rep.). SRI International, June 1979. (AD A072 146)

**DATA ELEMENT DEFINITION NR 198-012X**  
CTEC, Inc./Crane

The simulation facility at the University of Pennsylvania requires a data base which is representative of the real data normally available to task force command ships, in order to conduct experimental evaluations. CTEC, Inc. has analyzed the availability and content of operational data bases, such as the Ocean Surveillance Information System (OSIS), the ASW Command Control System (ASWCCS) and others, and has identified a subset of these data sufficiently realistic for the conduct of simulation experiments. A typical scenario has been generated to demonstrate the alerting capability which was developed by the University of Pennsylvania; a set of criteria for triggering the alerting system was specified, and a determination was made of the additional data base requirements imposed by these criteria. These data are now in the computer storage; both fixed and variable data are included, and algorithms are included to process the data in ways responsive to a variety of queries which users might make. This research was monitored by the Information Systems Programs of the Mathematical and Information Sciences Division. Funding: ONR

## Report

CTEC, Inc. Alert capability support (Tech. Rep. 7810022). October 1978. (AD A064 104)

## ARCHIVAL PUBLICATIONS

This section contains references to entries in the archival literature which have not been cited in previous editions of this booklet. The decision to include this section was made when it was learned that our previous booklets had led some people to conclude erroneously that ONR reports were the only means by which ONR investigators disseminated their findings. On the contrary, technical reports receive rather limited primary distribution, for the most part to addressees actively involved in associated programs. The technical reports serve as preliminary and advance information forwarded to avoid the lengthy lags often associated with archival publications. Briefings, conferences, workshops, newsletters and such are also commonly used to promote the diffusion of knowledge and its utilization. Special emphasis is placed on archival publication in refereed journals and "hardbacks". ONR expects and encourages investigators to publish their research in the open literature, thus submitting to the critical review of the broad scientific community and adding to the body of scientific knowledge. The references given in the "Archival Publications" section constitute the bulk of those which appeared recently. For a number of reasons, we have undoubtedly missed some. We apologize to the reader and to the authors whose writings are not cited. However, we take pride in the number and range of recent contributions to the scientific literature which acknowledge ONR support.

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## LIST OF ABBREVIATIONS

AFOSR	Air Force Office of Scientific Research
AFHRL	Air Force Human Resources Laboratory
AFSC (AMD)	Air Force Systems Command, Aerospace Medical Division
ARI	Army Research Institute
BuPers	Bureau of Naval Personnel
CNET	Chief of Naval Education and Training
DARPA	Defense Advanced Research Projects Agency
DCA	Defense Communications Agency
DIA	Defense Intelligence Agency
FEA	Federal Energy Administration
IPAC	Intelligence Command, Pacific
MEPCOM	Military Enlisted Processing Command
NADC	Naval Air Development Center
NAMRL	Naval Aerospace Medical Research Laboratory
NAVCOSSACT	Naval Command Systems Support Activity
NAVMAT	Naval Material Command
NAVSEA	Naval Sea Systems Command
NIE	National Institute of Education
NMPC	Naval Military Personnel Command
NMRDC	Naval Medical Research and Development Command
NOSC	Naval Ocean Systems Center
NPRDC	Navy Personnel Research and Development Center
NSF	National Science Foundation
NSRDC	Naval Ship Research and Development Center
NSWC	Naval Surface Weapons Center
NTEC	Naval Training Equipment Center
NTIS	National Technical Information Service
OASD (MRA&L)	Office of Assistant Secretary of Defense, Manpower, Reserve Affairs and Logistics
OSD (C <sup>3</sup> I)	Office of Secretary of Defense, Command, Control, Communication, Intelligence
OUSDR&E	Office of the Under Secretary of Defense, Research and Engineering
PMTc	Pacific Missile Test Center
TAEG	Training Analysis and Evaluation Group

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